Available online at www.sciencedirect.com
ScienceDirect
Computers & Industrial Engineering 51 (2006) 671–683
computers & industrial engineering
www.elsevier.com/locate/dsw

Predictive algorithm to determine the suitable time to change automotive engine oil ☆

Hong-Bae Jun [a,*], Dimitris Kiritsis [a,1], Mario Gambera [b,2], Paul Xirouchakis [a,3]

[a] *Ecole Polytechnique Fédérale de Lausanne (EPFL), Laboratory of Computer-Aided Design and Production (STI-IPR-LICP), Station 9, ME B1, CH-1015 Lausanne, Switzerland*
[b] *Centro Ricerche Fiat, Strada Torino 50, 10043 Orbassano (TO), Italy*

Received 30 November 2005; received in revised form 15 June 2006; accepted 15 June 2006
Available online 15 September 2006

Abstract

Recently, emerging technologies related to various sensors, product identification, and wireless communication give us new opportunities for improving the efficiency of automotive maintenance operations, in particular, implementing predictive maintenance. The key point of predictive maintenance is to develop an algorithm that can analyze degradation status of automotive and make predictive maintenance decisions. In this study, as a basis for implementing the predictive maintenance of automotive engine oil, we propose an algorithm to determine the suitable change time of automotive engine oil by analyzing its degradation status with mission profile data. For this, we use several statistical methods such as factor analysis, discriminant and classification analysis, and regression analysis. We identify main factors of mission profile and engine oil quality with factor analysis. Subsequently, with regression analysis, we specify relations between main factors considering the types of mission profile of automotive: urban-mode and highway-mode. Based on them, we determine the proper change time of engine oil through discriminant and classification analysis. To evaluate the proposed approach, we carry out a case study and have discussion about limitations of our approach.

Keywords: Predictive maintenance; Statistical methods; Degradation; Engine oil; Mission profile data

1. Introduction

Recently, with emerging technologies such as micro electro-mechanical sensors, and wireless and mobile tele-communication, it becomes possible to have a high level of visibility of vehicle information during its

☆ This manuscript was processed by Area Editor E.A. Elsayed.

* Corresponding author. Tel.: +41 21 693 7331; fax: +41 21 693 3509.
E-mail addresses: hongbae.jun@epfl.ch (H.-B. Jun), dimitris.kiritsis@epfl.ch (D. Kiritsis), mario.gambera@crf.it (M. Gambera), paul.xirouchakis@epfl.ch (P. Xirouchakis).
[1] Tel.: +41 21 693 5163; fax: +41 21 693 3553.
[2] Tel.: +39 11 9083 047; fax: +39 11 9083 083.
[3] Tel.: +41 21 693 2914; fax: +41 21 693 3553.

0360-8352/$ - see front matter
doi:10.1016/j.cie.2006.06.017

operation. It opens up new opportunities for improving the efficiency of vehicle operations. One of most challenging issues is predictive maintenance. Predictive maintenance may be similar to preventive maintenance in the sense that its goal is to prevent product abnormality in advance before abnormality occurs. However, the approach of predictive maintenance is different from the time-oriented approach of preventive maintenance. It focuses on the prediction of degradation process, which is based on the assumption that most abnormalities do not occur instantaneously, and usually there are some kinds of degradation process from normal states to abnormalities (Fu et al., 2004). Hence, unlike breakdown maintenance and preventive maintenance that concentrate on fault detection and diagnostics of components, predictive maintenance focuses on degradation monitoring and prognostics. It enables us to identify and solve latent problems in advance before vehicle damage occurs. In particular, under the new environment where we can easily access and receive vehicle status information in a ubiquitous way, we can make a prognosis of vehicle status, predict vehicle's abnormality, and execute proactive maintenance, i.e. do predictive maintenance.

One of the key points for implementing predictive maintenance is to develop an algorithm that can analyze degradation status of a vehicle and determine a predictive maintenance strategy, e.g. determine the best time to maintain a vehicle. If degradation status can be measured and detected in a real time manner, then predictive maintenance activities can be performed before degradation worsens or failure occurs. It can reduce unnecessary maintenance costs. Hence, it is important to develop a decision algorithm for determining the time of vehicle's abnormality in an efficient way.

In this study, we deal with a predictive maintenance method of engine oil of a vehicle. We develop a predictive algorithm to determine an efficient changing time of engine oil by analyzing its degradation status with mission profile data. Engine oil plays an important role in performance and longevity of an engine. Too short interval of engine oil change causes an increase of maintenance cost. On the contrary, too long interval gives rise to increased engine wear and even engine damage (Basu et al., 2000). In most cases, engine oil changes are typically performed according to mileage or calendar schedules that are based on average data for a wide variety of vehicles (EPA, 1999). However, this strategy is not efficient because the oil change interval should depend on the usage mode of a vehicle which can be identified by its mission profile data during its usage period. Depending on the type of a vehicle and its usage objective, the usage mode (hereafter called mission profile type) will be different. Some vehicles can be frequently used in a highway. Some vehicles can also be mainly used in an urban. Diverse mission profile types make the degradation process of engine oil different. Thus we should apply different time intervals to change engine oil considering the specific mission profile type of a vehicle. This approach will give us several advantages. For example, it can slow down engine degradation process by doing suitable maintenance actions in advance. Also, it can extend the life of an engine and reduce the cost of maintenance.

In developing a predictive maintenance algorithm for engine oil change, it is necessary to identify critical factors for detecting oil degradation status since several factors can affect the quality of engine oil during engine operations. Here, we will do it using mission profile data. Although oil sample analysis can give us the amount of contamination, wear rates, and other physical characteristics of engine oil, it is time-consuming and costly to get oil samples from an engine directly. Hence, instead of extracting oil samples, we propose a more effective approach using indicators of engine mission profile that can be easily provided by sensors or onboard vehicle computers.

The rest of the paper is organized as follows: In Section 2, we introduce previous relevant research. In Section 3, we address engine oil degradation and mission profile. Then, we propose a predictive maintenance algorithm in Section 4. In Section 5, we introduce a case study. Finally, we conclude our study with a discussion and further research topics.

2. Previous research

There have been several publications about predictive maintenance so far. For example, Lu, Kolarik, and Lu (2001) have described an approach for real-time reliability prediction under dynamic operating conditions with time-series analysis. In their work, physical performance was measured and forecasted across time to estimate reliability. Allella, Chiodo, and Pagano (2002) have presented a predictive maintenance program of circuit-breakers of an electric power system, based on a dynamic statistical on-line diagnosis. Grall, Dieulle,