Analysis of Timing Belt Vibrational Behavior During a Durability Test Using Artificial Neural Network (ANN)

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ABSTRACT
In this research, an intelligent method is introduced for prediction of remaining useful life of an internal combustion engine timing belt based on its vibrational signals. For this goal, an accelerated durability test for timing belt was designed and performed based on high temperature and high pre tension. Then, the durability test was begun and vibration signals of timing belt were captured using a vibrational displacement meter laser device. Three feature functions, namely, Energy, Standard deviation and kurtosis were extracted from vibration signals of timing belt in healthy and faulty conditions and timing belt failure threshold was determined. The Artificial Neural Network (ANN) was used for predicting and monitoring vibrational behavior of timing belt. Finally, the ANN based on Energy, Standard deviation and kurtosis features of vibration signals could predict timing belt remaining useful life with accuracy of 98%, 98% and 97%, respectively. The correlation factor (R²) of vibration time series prediction by ANN and based on Energy, Standard deviation and kurtosis features of vibration signals were determined as 0.87, 0.91 and 0.87, respectively. Also, Root Mean Square Error (RMSE) of ANN based on Energy, Standard deviation and kurtosis features of vibration signals was calculated as 3.6%, 5.4% and 5.6%, respectively.

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Bayesian theory

Prognostics Center of Excellence (PCoE), University of Cincinnati.

SVM

Dempster-Shafer evidence theory

PHM

Dempster-Shafer evidence theory

Dempster-Shafer evidence theory
بررسی رفتار ارتقاء نسخه زمان‌بندی در آزمون دوام کلمه

فصل ۴

در این بخش از فصل دوم اعم و موردی نظیره فلسفه جهت لیست ارتقاء نسخه در حالت مختلف استفاده شد. یک اساسی باعث از نظر شخصیت زمان‌بندی شده، زمان‌بندی پیش نشده و دنبال نسبت زمان‌بندی در این روش به روش شخصیت زمان‌بندی پیش نشده.

جدول ۲ مشخصات سگرلک ارتباط‌برداری

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | ---
| زمان‌بندی | ۱۳۹۵

* Run to failure data
<table>
<thead>
<tr>
<th>Faults characterisation</th>
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<tr>
<td>Data mining</td>
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<tr>
<td>Signal processing</td>
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Fig. 1 The proposed method in this research for timing belt life prediction

جدول ۱ نام و الفبایی نسخه ارتباطی زمان‌بندی

<table>
<thead>
<tr>
<th>فرمول</th>
<th>نام ویژگی</th>
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<tbody>
<tr>
<td>$F_2 = \sum_{n=1}^{N} (x(n) - M)^2$</td>
<td>انرژی</td>
</tr>
<tr>
<td>$F_3 = \sum_{n=1}^{N} (x(n) - M)^4$</td>
<td>انحراف از معیار</td>
</tr>
<tr>
<td>$F_4 = (N - 1) \cdot F_2^4$</td>
<td>$t$-واترم نسبت به معیار</td>
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Fig. 2 Experimental test rig of this research

Fig. 3 Overloading condition in the timing belt

1 Multi-Layer Perceptron (MLP)
2 Supervised Learning
3 Levenberg-Marquardt
4 Targets

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Fig. 6 Thresholding of failure based on standard deviation of vibration signals

Fig. 7 Thresholding of failure based on kurtosis of vibration signals

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Fig. 9 The predicted and real values of standard deviation feature of vibration signals

Fig. 10 The predicted and real values of kurtosis feature of vibration signals

Fig. 8 The predicted and real values of energy feature of vibration signals

Fig. 9 The predicted and real values of standard deviation feature of vibration signals

Fig. 10 The predicted and real values of kurtosis feature of vibration signals

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