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Short communication

A comparative study of adaptive filters in detecting a naturally degraded bearing within a gearbox

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ABSTRACT

The diagnosis of bearing faults at the earliest stage is critical in avoiding future catastrophic failures. Many diagnostic techniques have been developed and applied in for such purposes, however, these traditional diagnostic techniques are not always successful when the bearing fault occurs within a gearbox where the vibration response is complex; under such circumstances it may be necessary to separate the bearing vibration signature.

This paper presents a comparative study of four different techniques for bearing signature separation within a gearbox. The effectiveness of these individual techniques were compared in diagnosing a bearing defect within a gearbox employed for endurance tests of an aircraft control system. The techniques investigated include the least mean square (LMS), self-adaptive noise cancellation (SANC) and the fast block LMS (FBLMS). All three techniques were applied to measured vibration signals taken throughout the endurance test. In conclusion it is shown that the LMS technique detected the bearing fault earliest.

1. Introduction

Monitoring of machine vibration for early fault detection is widely applied [1,2]. The vibration signals from machines contain multiple sources which can be corrupted by noise from the transmission path. The diagnosis of bearing faults in gearboxes is not without its challenges [3,4], therefore methods of enhancing the signal to noise ratio (SNR) are required [5]. This is particularly the case in gearboxes where the gear mesh contribution to the overall vibration is of such significance as to mask bearing fault frequencies [6,7]. In practice, envelope analysis has been used to extract the bearing fault vibration signature in gearboxes, though in some cases envelope analysis has failed to reduce the gear mesh contribution to the total vibration signal. In such instances a narrow band-pass filter at high frequency has been applied to separate the high frequency component excited by bearing impacts [8].

Recently, signal separation techniques have been applied in the diagnosis of bearing faults within gearboxes. The separation is based on decomposing the signal into deterministic and random components. The deterministic part represents the gear component and the random part represents the bearings component of vibration. The bearing contribution to the signal is expected to be random due to slip effects [9].

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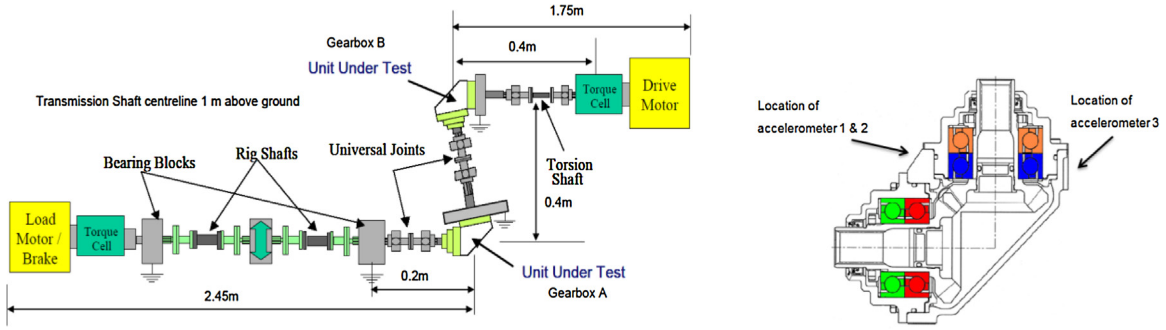

Fig. 1. Test rig layout (left) and gearbox configuration (right).

Table 1
Load cycles characteristics summary.

Cycle type	1	2	3	4	5	6	7	8	9
Times applied during bearing life	18296	22869	4574	462	462	2200	6600	4620	41580
Duration (s)	131	131	131	350	42	71	268	52	52
Torque max. (Nm)	126.1	126.1	158.6	126.1	126.1	42.8	42.8	12.4	97.7

More recently, the use of adaptive filters has been applied to monitor bearings [10,11]. This concept is based on the Wold Theorem, in which the signal can be decomposed into deterministic and non-deterministic parts [12]. The separation is based on the fact that the deterministic part has a longer correlation than the random part and therefore the autocorrelation is used to distinguish the deterministic part from the random part. However a reference signal is required to perform the separation. The application of this theory in condition monitoring was established by Chaturvedi et al. [13] where the Adaptive noise cancellation (ANC) algorithm was applied to separate bearing vibrations corrupted by engine noise with the bearing vibration signature used as a reference signal for the separation process. However, for practical diagnostics, the reference signal is not always readily available. As an alternative a delayed version of the signal has been proposed as a reference signal and this method is known as Self-adaptive noise cancellation (SANC) [14] which is based on delaying the signal until the noise correlation is diminished and only the deterministic part is correlated.

Three algorithms were compared to assess their effectiveness in diagnosing a bearing defect in a gearbox; least mean square (LMS), self-adaptive noise cancellation (SANC) and fast block LMS (FBLMS). These algorithms were applied to decompose the measured vibration signal into deterministic and random parts with the latter containing the bearing signal. This investigation assesses the merits of these techniques in identifying a natural degraded bearing under conditions of relatively large background noise. The gearbox considered in this study is part of a transmission system of an aircraft control system which suffered premature bearing failure at an early stage of testing; therefore, these algorithms will be applied to examine their ability to identify the failure at the onset of degradation.

2. Theoretical background

2.1. Adaptive filter

An adaptive filter is used to model the relationship between two signals in an iterative manner; the adaption refers to the method used to iterate the filter coefficient. The adaptive filter solution is not unique however the best solution is that which is closest to the desirable response signal. FIR filters are more commonly used as adaptive filters in comparison of IRR filters [15].

Table 2
Bearing faults frequencies.

Parts	Frequency (Hz)
Shaft speed frequency (SS)	11.8
Gear mesh frequency (GM)	201.2
Inner race defect frequency (IRD)	83.2
Outer race defect frequency (ORD)	58.8
Cage defect frequency	4.9
Ball spin frequency	25.6
Rolling element defect frequency	51.2