Application of Linear Prediction, Self-Adaptive Noise Cancellation and Spectral Kurtosis in Identifying Natural Damage of a Rolling Element Bearing in a Gearbox

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The ability to detect and diagnose faults in rolling element bearings is crucial for modern maintenance schemes. Several techniques have been developed to improve the ability of fault detection in bearings using vibration monitoring, especially in those cases where the vibration signal is contaminated by background noise. Linear Prediction and Self-Adaptive Noise Cancellation are techniques which can substantially improve the signal to noise ratio of the signal, improving the visibility of the important signal components in the frequency spectrum. Spectral Kurtosis has been shown to improve bearing defect identification by focusing on the frequency band with a high level of impulsiveness. In this paper the ability of these three methods to detect a bearing fault is compared using vibrational data from a specially designed test rig that allowed fast natural degradation of the bearing. The results obtained show that the Spectral Kurtosis was able to detect an incipient fault in the outer race of the bearing much earlier than any other technique.

NOMENCLATURE

$a(k)$	Weight attached to each observation in LP
ANC	Adaptive Noise Cancelling
e	Output in ANC and SANC
f	Frequency
GM	Gear mesh frequency
H	Filter length
IRD	Inner race defect frequency
K	Kurtosis
LF	Line Frequency
LP	Linear prediction
n	Time point
N	Number of past samples considered in the calculation of R_τ
n_0	Reference noise
n_1	Uncorrelated eference noise
ORD	Outer race defect frequency
p	Number of past samples considered in LP
R_τ	Autocorrelation function
S	Signal of interest in ANC/SANC
SAN	Self-Adaptive Noise Cancellation
SK	Spectral Kurtosis
SNR	Signal to Noise Ratio
SS	Shaft speed frequency
W	Vector of filter coefficients
w	Filter weights in ANC and SANC
x	Random signal
$\hat{x}(n)$	Predictable part of signal x at
$y(n)$	Filter output
Δ	Time delay
Δf	Frequency band width
μ	Forgerring factor
μ	Average value
σ	Standard deviation

1. INTRODUCTION

Rolling element bearings are important components in rotating machinery. By monitoring the vibration signature of bearings, it is possible to obtain important information about their condition and use this information to improve the maintenance strategy. Diagnostic techniques based on vibration are mainly concerned with the extraction of defect features in the acquired signal, which can be related to the healthy or defective state of vital parts in a machine. Many different diagnostic methods have been successfully used to identify machine faults, processing the vibration signal in the time or frequency domain, in order to locate and quantify any existing damage. In complex machines the signal acquired is normally inclusive of additive background noise from other machine components or subsystems, which can make it difficult or sometimes impossible to identify the fault patterns in the signal.

In the case of bearings, the fault is produced typically by the damage of the surface of the inner or outer race or the rolling elements. When a damaged surface contacts another rolling surface, a force impulse is generated, which excites resonances in the bearing and the machine.[1] The successive impacts generate a vibration signal, which often has an impulsive repeti-