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Feedback on the Surveillance 8 challenge: Vibration-based diagnosis of a Safran aircraft engine

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ABSTRACT

This paper presents the content and outcomes of the Safran contest organized during the International Conference Surveillance 8, October 20–21, 2015, at the Roanne Institute of Technology, France. The contest dealt with the diagnosis of a civil aircraft engine based on vibration data measured in a transient operating mode and provided by Safran. Based on two independent exercises, the contest offered the possibility to benchmark current diagnostic methods on real data supplemented with several challenges. Outcomes of seven competing teams are reported and discussed. The object of the paper is twofold. It first aims at giving a picture of the current state-of-the-art in vibration-based diagnosis of rolling-element bearings in nonstationary operating conditions. Second, it aims at providing the scientific community with a benchmark and some baseline solutions. In this respect, the data used in the contest are made available as supplementary material.

1. Introduction

1.1. Context

The organization of a contest in an international conference is a unique occasion to assess the state of the art in a particular area. In this respect, the Safran contest which took place during the Conference Surveillance 8, October 20–21, 2015, at the Roanne Institute of Technology, France, gave rise to several interesting outcomes which surely worth a publication. The

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List of acronyms

Acc0	accelerometric signal used in Exercise 1
Acc1	signal from accelerometer 1 used in Exercise 2
Acc2	signal from accelerometer 2 used in Exercise 2
COT	Computer Order Tracking
EKF	Extended Kalman Filter
EKF-NST	Extended Kalman Filter NonStationary Sinusoid Tracker
evp	event per revolution
FK	Fast Kurtogram
HVD	Hilbert Vibration Decomposition
IAS	Instantaneous Angular Speed
IF	Instantaneous Frequency
MAD1	Mean Absolute Deviation
MAD2	Median Absolute Deviation
MOPA	Multiple Order Probabilistic Approach
PDF	Probability Density Function
PSD	Power Spectral Density
SK	Spectral Kurtosis
SNR	Signal to Noise Ratio
SR	Stochastic Resonance
SRCK	Square-Root Curbature Kalman Filter
Tacho	Tachometric signal used in Exercise 2
SA	Synchronous Average
sps	samples
TQR	Time-Quefrency Representation

contest dealt with the diagnostics of bearing faults in a civil aircraft engine from vibration data provided by Safran. The difficulty of the problem was thus representative of the complexity encountered in the aeronautic industry and required from the contestants a high degree of expertise in signal processing and in data analysis.

The data and assignment (hereafter introduced in Section 2.1) were sent to the contestants two weeks before the starting date of the conference. This relatively short period of time emulated the benchmark of cutting edge techniques developed and used by various international teams, yet still leaving room for testing new ideas.

1.2. Scientific challenges

The contest assignment was divided in two exercises which are described in Section 2.2 of the present paper. The first exercise dealt with the recovery of the instantaneous angular speed (IAS) of the high-pressure (HP) shaft from a vibration signal measured by an accelerometer in transient operating mode. The second exercise dealt with the detection of one or more damaged bearings from the vibration signals returned by two accelerometers and measured in transient operating mode.

The two exercises were formulated such as to reflect the current issues encountered in the diagnosis of complex systems. It happens that they address rather similar objectives as in a recent contest organized within the CMMNO'14 Conference [1]. Although this reflects the fact that condition monitoring is faced with some everlasting issues – i.e. the diagnosis of bearing under nonstationary operation – the CMMNO'14 contest dealt with a different system (the gearbox of a windturbine) and involved different challenges (in particular the fact that the fault signatures occurred at very low speed). The challenges of the present contest are briefly introduced hereafter.

The estimation of the IAS (Exercise 1) is of primary interest in vibration-based condition monitoring of systems operating under nonstationary conditions. In particular, knowledge of the IAS is a fundamental condition for the implementation of specific signal processing techniques such as order analysis and tracking, synchronous processing, and angular resampling. The importance of the topic is for instance well reflected in the comprehensive literature review [2] and in the recent MSSP Special Issue [3]. One current challenge is to estimate the IAS directly from the vibration signal in order to address the case when no encoder is made available due to cost or technological reasons. This is a situation for which no versatile methods seem available to date. The problem is generally known to be difficult, especially when the vibration signal contains several components which are not necessarily harmonically related. In the present case, another difficulty was due to the fact that the fundamental of the IAS was too weak to be tracked directly. Questions also arose as how to deal with weak or fading harmonics, with crossing harmonics, and how to possibly gain information from multiple harmonics.

The detection of bearing faults (Exercise 2) is a more classical problem which has been attacked by several approaches in the literature. Yet, some major difficulties are still persisting, which were illustrated in the contest. A first difficulty was due

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