



INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

Name of the Student : RAPUR JANANI SHRUTI

Roll Number : 146103018

Programme of Study : Ph.D.

Thesis Title: DIAGNOSIS OF MULTIPLE INDEPENDENT AND COEXISTING MECHANICAL AND HYDRAULIC CENTRIFUGAL PUMP FAULTS USING SUPPORT VECTOR MACHINE BASED METHODOLOGIES

Name of Thesis Supervisor(s) : Prof. RAJIV TIWARI

Thesis Submitted to the Department/ Center : MECHANICAL ENGINEERING

Date of completion of Thesis Viva-Voce Exam : 02 – MAY – 2019

Key words for description of Thesis Work : CONDITION BASED MAINTENANCE, CENTRIFUGAL PUMPS, FAULTS DIAGNOSIS, MACHINE LEARNING, SVM

SHORT ABSTRACT

Reliable detection and isolation of centrifugal pump (CP) faults is a challenging and important task in the modern industries. Hence, this study proposes, machine learning based multi-fault detection of CPs driven by induction motor. The intelligent fault detection methodology is developed based on the multi-class support vector machine (SVM). The mechanical and hydraulic faults in CPs are mutually dependent and therefore may exist concurrently. Hence, in the present research, an assortment of various flow instabilities like, the suction flow blockages, discharge flow blockages, pseudo re-circulation and dry runs are considered coexisting with mechanical faults, like the impeller cracks and pitted cover plate faults. In addition, the suction and discharge CP blockages are considered with five levels of varying severity. A total of thirty-three faults are considered on the CP. In order to generate relevant fault signatures of CP faults, vibration signals in three orthogonal directions and current signals of all three phases have been acquired for a wide range of operating conditions (i.e., the speed) in time domain using an experimental test rig.

The fault diagnostics of CPs has been performed using features extracted independently from the time domain, frequency domain and time-frequency domains. The time-frequency domain data is obtained by transforming the time domain data using the continuous wavelet transform (CWT) and the wavelet packet transform (WPT) approaches. As the prediction accuracy highly depends on features, the wrapper model is used to select the most suitable features in each of the considered domains. These features are further used as inputs to SVM classifiers. The grid-search technique along with the cross-validation is adapted to select optimal SVM parameters required to build a reliable SVM model. This model is used for fault predictions. The advantage of simultaneously using the vibration and current based features on the fault classification accuracy of mechanical and hydraulic CP faults has been established. Prediction performances have been checked with the low and high sampling rate of data acquisition using time domain and frequency domain data. If a defect exists at any stage the classifier identifies it, isolates it and establishes its severity. In the case of wavelet transform, several mother wavelets are considered to study the effects of them on the CP fault diagnosis.

The fault diagnosis is performed for wide range of distinct operating speeds of CPs. In order to check the robustness of the proposed methodology, the trained classifier is tested with features extracted from corrupted data. The data corruption is performed by adding white Gaussian noise at different signal to noise ratios to the baseline signals

acquired from experimentation. The fault diagnosis in this study is also extended to the intermediate speed cases to check the classification ability of the developed method to account for unavailability of data at certain speeds of CP operation.

This investigation establishes that the vibration signatures are very useful and in most cases sufficient for the CP fault diagnosis. However, the addition of the features extracted from the motor line-current signatures improves the classification performance of the developed algorithm. All the methodologies developed based on different domains demonstrated that there is no or less operational speed dependence on the fault classification performance. However, for an intermediate speed case it is found that there is some operation speed dependence as the fault manifestation changes significantly with the CP speed. The identification of fault severity is much more complicated than identifying faults belonging to different fault families. This is because faults that belong to same family with slight variations in severity produce similar fault signatures and therefore similar fault features. The developed methods also show robustness in performance even when the data is corrupted with additive noise.

