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Fault Diagnosis Of Bearings Using Classification Algorithms

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Abstract- *Timely detection of faults in bearings can save time, efforts and maintenance costs of rotating equipments. To avoid the physical connection of vibration pickup to the machine tool, a non-contact type vibration pickup has been designed and developed in this study to acquire the vibration data for bearing health monitoring under load and speed variation. Fault diagnosis has been accomplished using a Hilbert transform for denoising the signal. The dimensionality of the extracted features was reduced using Principal Component Analysis (PCA) and thereafter the selected features were ranked in order of relevance using the Sequential Floating Forward Selection (SFFS) method for reducing the number of input features and finding the most optimal feature set.*

Finally, these selected features have been passed to Support Vector Machines (SVM) and Artificial Neural Networks (ANN) for identifying and further classifying the various bearing defects. A comparative analysis of the effectiveness of SVM and ANN has been carried out.

I. INTRODUCTION

Careful selection and location of sensors are of key importance in the construction and implementation of an effective condition monitoring system. There is a continual call for depletion of maintenance and operational costs of rotating machine elements. Health monitoring of bearings, which is regarded as a crucial component of rotating machinery, is expected to facilitate in the preclusion of machine breakdown and ensure the machine availability by maintenance actions in time. The effectiveness and reliability of measurement approaches for monitoring the condition of the bearing are influenced by both the signal processing techniques and locations of the sensors selected for fault characteristic extraction. This paper proposes a low cost Non-contact optimal sensor placement (NC-OSP) methodology in order to get information of high quality related to the dynamic features of the machines. Experiments were conducted using different bearing conditions under different operating conditions and sensor placement positions. Mathematical models have been proposed based on the response parameters and input variables experimentation using response surface methodology. Results indicate that the most effective input variable to control the response parameters *viz.* FFT vibration amplitude of characteristic frequency and RMS value of time domain was the shaft speed followed by load and angle of incidence. The responses proposed by the optimal models have been observed at 8° angle of incidence with maximum load and speed. The optimal outcomes have been validated experimentally which proved that the predicted results were in sync with the actual ones. The proposed work has significant potential in industrial environment with complex systems, where the condition monitoring approach with proper placement of sensors can play an important role.

II. LITERATURE REVIEW

It is vital to find flaws at an early stage in design, components, material, or manufacturing during the initial phase. This review paper attempts to summarize past development and recent advances in the areas about green manufacturing, maintenance, remaining useful life (RUL) prediction, and like. The current state of the art in reliability research for electronic components, mainly includes failure mechanisms, condition monitoring, and residual lifetime evaluation is explored. A critical analysis of reliability studies to identify their relative merits and usefulness of the outcome of these studies' vis-a-vis green manufacturing is presented. The wide array of statistical, empirical, and intelligent tools and techniques used in the literature are then identified and mapped. Finally, the findings are summarized, and the central research gap is highlighted.

This paper provides an overview of the studies hitherto conducted in the area of component reuse, maintenance, diagnostics, prognostics, and residual useful life prediction using different techniques. Most of the maintenance techniques address the maintenance-free life prediction of large plants and equipment only. The existing maintenance practices mainly aim at repairing or replacing the failed components. These procedures ignore the potential of reuse capability of these components/parts.

The prudent approach effectively utilizing the reuse potential of these otherwise discarded components would go a long way in making a substantial saving in production and labor cost as also in achieving the objectives of reliable electronic industry. Therefore, there is a strong need for developing simple methods to identify the reuse potential (RUL) of used components and parts. The failure prediction of one component can save the entire system and warns the user to replace the component with the operating one immediately.

IV. SYSTEM MODULES

4.1 Single Preprocessing

Bearing with local faults produces high-frequency vibration modulated by pulse force during operation. Signal demodulation is necessary to attain the defect characteristic frequencies. Envelope analysis has been acknowledged as an effective strategy for identifying the incipient failure of bearings in a high noise environment. The non-linear process produces frequency components that are not in the spectra of raw signals. The spectra of the modulated signal comprise a peak at the carrier frequency with sidebands placed at the modulation frequency. In the present study, the signal envelope has been obtained using the HT technique for different bearing conditions. The term 'envelope analysis' related to the series of procedures mentioned.The signal envelope includes data on the periodic impulse and the severity level in each impulse, so the fault 198 characteristic factors identified from the signal envelope should accurately show the working condition and fault pattern. The effect of envelope analysis on raw vibration signal and its corresponding spectra for outer race bearing defect (at 1600 rpm and 4 kg load).

4.2 Feature extraction and dimensionality reduction

The motive of the feature selection algorithm is to choose the best characteristics rich in discerning information regarding the classification problem. The remaining PCA based selected features were ranked using the SFFS algorithm. The sequential feature selection algorithms belong to the class of wrapper based searching procedures for determining an efficient subset of features by aggregating the best features or eliminating the worst features iteratively. The sequential feature algorithms reduce an original d-dimensional feature space to a k-dimensional feature sub-space where $k < d$. The two-fold advantage of using a feature selection is to increase the computational efficiency and to improve the model generalization by removing noise and irrelevant features.

4.3 Training and testing:

The vibration features obtained from raw and preprocessed signals using both contact and non-contact sensors were trained and tested for bearing fault classification using SVM and ANN. Total instances and features (11 for raw signal and 13 for envelope signal) have been used for the study including statistical parameters for each of the bearing conditions, rotor speed and the number of loads used.

4.5 Fault detection using SVM:

The extracted and selected features obtained from both raw and envelope signals were used for classifying the bearing faults using SVM classifier with different kernel functions i,e. Linear, Quadratic, Cubic, and Gaussian. The kernel functions were evaluated to observe their suitability for the given classification problem. The 'one versus-one' methodology was used to train the SVM classifier, where the total number of classes was four. Accuracies were computed for each combination of features in order of relevance. A 5-fold cross-validation scheme was adopted for the evaluation of the SVM classifiers.

4.6 Fault detection using ANN:

In this work hidden layer with 4 computation nodes (i,e. 5, 10, 15 and 20) has been used. For training purposes, the parameters of the applied BPNN are listed in Table IV. The training would stop if any one of the conditions given in Table IV were encountered. The network weights and biases were initialized randomly by the program. The relevant feature matrix obtained from raw data was divided into three categories, i.e. 70% training data, 10% validation data and 20% testingdata to evaluate the performance of neural network classifier. These sets were randomly chosen;hence five repetitions were made to compute the mean value of the output matrix.

V. RESULTS AND DISCUSSION

This section describes the results obtained for different fault conditions of bearing using svm and ann. For the prediction of multi-class, the outcome on a test set is frequently shown as a 2d confusion matrix (or contingency table), consists of a column and a row for each class. Each element of the matrix reveals the number of trial samples for which the predicted class is the column and the true class is therow. The outcomes correlate to huge numbers down the main diagonal and preferably zero, small, off-diagonal elements give a precise prediction. The selection of fault as a characteristic for class initiates the categorization process and the classifier output comprises of detailed accuracy by class, confusion matrix, and assessment of the favorable numeric prediction. the confusion matrix of the fine-gaussian svm (fg-svm) classifier for identifying the different bearing faults for raw and envelope signals using acc and ncs is listed in table v. For raw signal, the confusion matrix shows the combination of all vibration features and sffs selected six features using acc have the highest classification accuracy of 100% and 99% respectively for rolling element defect. The misclassification rate was highest for h and or defect. However, ncs shows the highest classification accuracy of 97% and 95% with acombination of all 11 vibration features and most relevant features respectively in case of bd as compared to other fault conditions.Also as in the case with accelerometer-based fault classification, the misclassification rate between h and or defect was observed to be highest with ncs.

VI. CONCLUSION

This study, a laser beam based non-contact vibration pickup has been designed and developed for measuring machine vibrations. The acquired signals were preprocessed using a Hilbert transform. PCA and SFFS were utilized for eliminating redundant features and selecting the features in order of relevance. Finally, the selected features were passed to SVM and ANN for classification and performance evaluation The vibration signatures obtained from developed noncontact sensor compare well with the accelerometer data obtained under the same conditions. ANN outperformed SVM with a maximum success rate of 93.3% and 94.2% for raw vibration signals acquired using NCS and ACC respectively, whereas 97.2% and 98.3% for envelope signals using NCS and ACC.The outcomes reveal that proposed non-contact sensor can be used to develop a proactive robust condition-based maintenance system to preclude catastrophic failures and diminish operating cost.

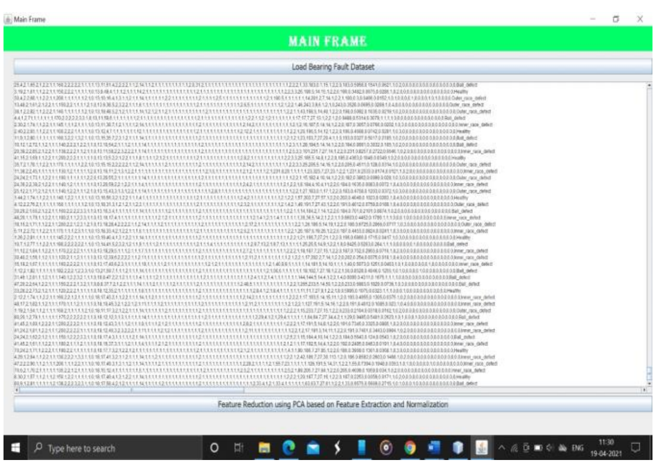

Fig No 1:Main frame

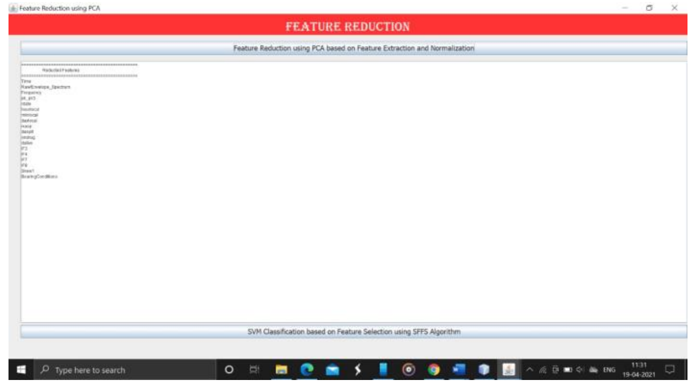

Fig No 2:Feature Reduction

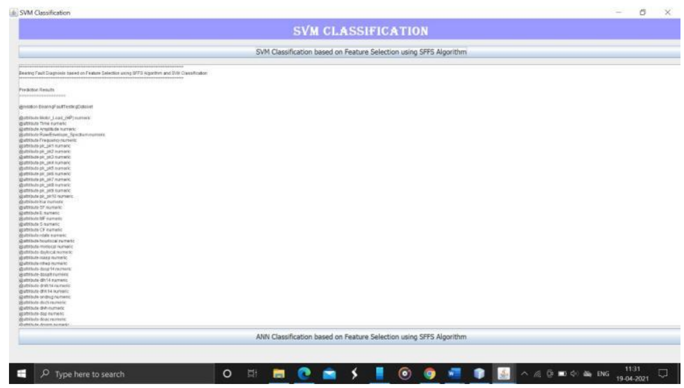

Fig No 3:SVM classification

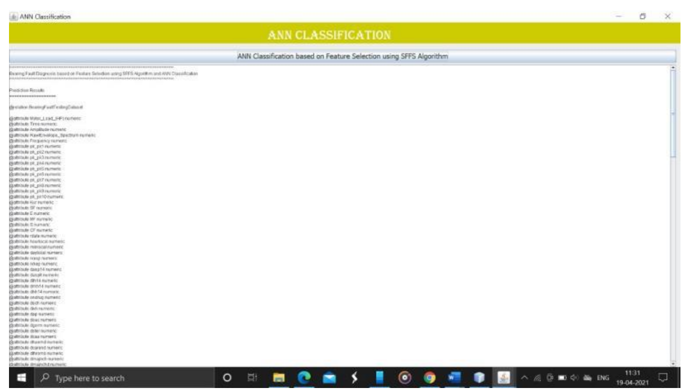

Fig No 4:ANN classification

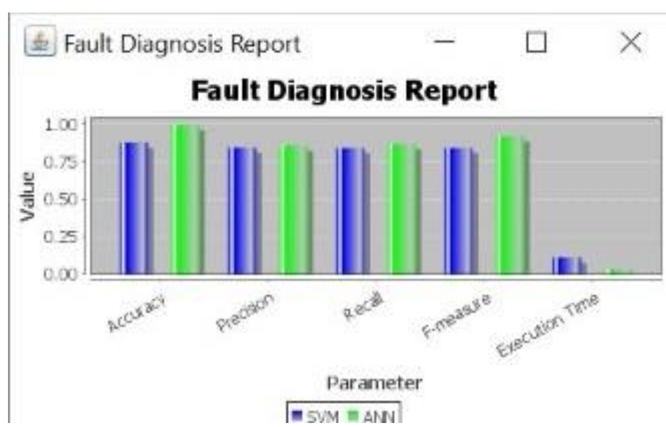

Fig No 5:Fault Diagnosis Report

REFERANCES

[1] Deepam Goyal, S.S. Dhami and B.S. Pabla,"Non-Contact Fault Diagnosis of Bearings in Machine Learning Environment,"DOI10.1109/JSEN.2020.2964633, IEEE Sensors Journal

[2] S. Sehgal and H. Kumar, “Damage detection using derringers function 465 based weighted model updating method,” in Structural Health Monitor466 ing, Volume 5, pp. 241–253. Springer, 2014.

[3] A. Glowacz, “Fault diagnosis of single-phase induction motor based on acoustic signals,” Mechanical Systems and Signal Processing, vol. 117, pp. 65–80, 2019.

[4] C. A. Tokognon, B. Gao, G. Y. Tian, and Y. Yan, “Structural health monitoring framework based on internet of things: A survey,” IEEE Internet of Things Journal, vol. 4, no. 3, pp. 619–635, 2017.

[5] T. Haj Mohamad, M. Samadani, and C. Nataraj, “Rolling element bearing diagnostics using extended phase space topology,” Journal of492 Vibration and Acoustics, vol. , no. 6, 2018.

[6] R. Liu, B. Yang, E. Zio, and X. Chen, “Artificial intelligence for fault diagnosis of rotating machinery: A review,” Mechanical Systems and Signal Processing, vol. , pp. 33–47, 2018.

[7] D. Goyal, B. Pabla, S. Dhami et al., “Non-contact sensor placement strategy for condition monitoring of rotating machine-elements,” Engi518 neering Science and Technology, an International Journal, vol. 22, no. 2, pp. 489–501, 2019.

[8] D. Goyal and B. Pabla, “The vibration monitoring methods and sig461 nal processing techniques for structural health monitoring: A review,”462 Archives of Computational Methods in Engineering, vol. 23, no. 4, pp. 585–594, 2016

[9] L. Saidi, J. B. Ali, and F. Fnaiech, “Application of higher order spectral features and support vector machines for bearing faults classification,” ISA transactions, vol. 54, pp. 193–206, 2015.

[10] A. Choudhary, D. Goyal, S.L. Shimi, A. Akula, Condition monitoring and fault diagnosis of induction motors: a review, Arch. Comput. Methods Eng. (2018) 1–18. 10.1007/s11831-018-9286-z.

[11] S. Kumar, D. Goyal, S.S. Dhami, Statistical and frequency analysis of acoustic signals for condition monitoring of ball bearing, Mater. Today: Proc. 5 (2018) 5186–5194.

[12] D. Goyal, Vanraj, B.S. Pabla, S.S. Dhami, Condition monitoring parameters for fault diagnosis of fixed axis gearbox: a review, Arch. Computer. Methods Eng. 24 (2017) 543–556.

[13] Vanraj, B.S. Pabla, S.S. Dhami, Optimization of sound sensor placement for condition monitoring of fixed-axis gearbox, Cogent Eng. 4 (2017) 1345673.

[14] D. Goyal, B.S. Pabla, Development of non-contact structural health monitoring system for machine tools, J. Appl. Res. Technol. 14 (2016) 245–258

[15] W. Xiao, B. Wang, J. Zhou, W. Ma, L. Yang, Optimization of aluminium sheet hot stamping process using a multi-objective stochastic approach, Eng. Optim. 48 (2016) 2173–2189.

[16] D. Goyal, B.S. Pabla, Condition based maintenance of machine tools-a review, CIRP J. Manuf. Sci. Technol. 10 (2015) 24–35.

[17] D. Goyal, B.S. Pabla, S.S. Dhami, K.C. Lachhwani, Optimization of condition based maintenance using soft computing, Neural Comput. Appl. (2016) 1–16

[18] K. M. Sousa, I. B. V. da Costa, E. S. Maciel, J. E. Rocha, C. Martelli, and J. C. C. da Silva, “Broken bar fault detection in induction motor by using optical fiber strain sensors,” IEEE Sensors Journal, vol. 17, no. 12, pp. 3669–3676, 2017.

[19] R. P. Linessio, K. de Morais Sousa, T. da Silva, C. A. Bavastri, P. F. da Costa Antunes, and J. C. C. da Silva, “Induction motors vibration monitoring using a biaxial optical fiber accelerometer,” IEEE Sensors Journal, vol. 16, no. 22, pp. 8075–8082, 2016

[20] M. Xia, T. Li, T. Shu, J. Wan, Z. Wang et al., “A two-stage approach for the remaining useful life prediction of bearings using deep neuranetworks,” IEEE Transactions on Industrial Informatics, 2018.