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Intelligent bearing diagnostics using wavelet support vector machine

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Abstract

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Abstract

This paper deals with implementation of intelligent system for fault diagnostics of rolling element bearing . In this work, the proposed intelligent system was basically created using support vector machine (SVM) due to its excellent performance in classification task. Moreover, SVM was modified by introducing wavelet function as kernel for mapping input data into feature space. Input data were vibration signals acquired from bearings through standard data acquisition process. Statistical features were then calculated from bearing signals, and extraction of salient features was conducted using component analysis. Results of fault diagnostics are shown by observing classification of bearing conditions which gives plausible accuracy in testing of the proposed system. © (2014) Trans Tech Publications, Switzerland.

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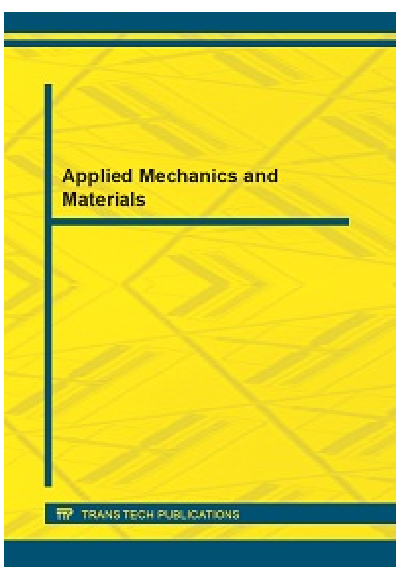

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Intelligent Bearing Diagnostics Using Wavelet Support Vector Machine

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Keywords: fault diagnostics, rolling element bearing, intelligent system, support vector machine.

Abstract. This paper deals with implementation of intelligent system for fault diagnostics of rolling element bearing. In this work, the proposed intelligent system was basically created using support vector machine (SVM) due to its excellent performance in classification task. Moreover, SVM was modified by introducing wavelet function as kernel for mapping input data into feature space. Input data were vibration signals acquired from bearings through standard data acquisition process. Statistical features were then calculated from bearing signals, and extraction of salient features was conducted using component analysis. Results of fault diagnostics are shown by observing classification of bearing conditions which gives plausible accuracy in testing of the proposed system.

Introduction

Condition monitoring of rolling element bearings for early detection and diagnostics of faults to prevent catastrophic failure is important in industry. As main component in rotating machine, rolling element bearing needs good attention from maintenance operator to guarantee their reliability when the machines operate. Industry may loss their profit if they deny the procedure of bearing condition monitoring dan fault diagnostics.

Condition monitoring and faults diagnostics are multi-disciplinary and integrated technology. It consists of the knowledge of intelligent system and the other parts such as analysis of vibration signal, current, temperature or even all of acquired signal from data acquisition. So it depends on how and which parts the intelligent knowledge will be dealt with. Developing intelligent system, combining modern signal analysis and soft computing theory, data mining, realizing the real-time, online dynamic monitoring, is a developmental direction to reach relatively best performance in condition monitoring and faults detection of machine.

Recently, many advanced technology and intelligent methods have been developed such as the use of support vector machine (SVM) combining with wavelet transform [1], neural network [2], and genetic algorithm [3] to perform faults detection. However, the research in this area is still open issue. The use of SVM [4] as intelligent classifier tool becomes popular due to its good performance. Compared with artificial neural network (ANN), SVM do not have some problem such as local minimization, the number selection of nodes in hidden layer and the dimension disaster. SVM which is based on statistical learning theory (SLT) is widely gaining application in the area of machine learning, data classification and pattern recognition because of the high accuracy and good generalization capability [5].

In this paper, a relatively new kernel trick using wavelet function is proposed. In this method, wavelet function is performed as kernel function and then inducing in SVM theory. The researchers who contribute the theoretical development of wavelet kernel are reported in references: reproducing wavelet kernel [6], construction of support wavelet network [7], application wavelet support vector to regression [8, 9], least square wavelet support vector [10]. However, the application is still rare in faults detection and classification of rolling element bearing. So it becomes a chance to built and establish an intelligent faults detection and classification of rolling element bearing using wavelet support vector machine called W-SVM.

In addition, this paper also introduced the use of component analysis using independent component analysis, principal component analysis and their kernel for feature reduction and extraction. This method is performed to overcome the huge of dimensionality phenomenon that tends to decrease the performance of classifier. Finally, a new intelligent faults detection and classification

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Design online artificial gain updating sliding mode algorithm: applied to internal combustion engine

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Keywords: internal combustion engine, sliding mode controller, sliding mode fuzzy controller, on-line sliding fuzzy gain scheduling sliding mode control.

Abstract. This paper presents an online Artificial Fuzzy sliding Gain Scheduling Sliding Mode Control (AFSGSMC) design and its application to internal combustion (IC) engine high performance nonlinear controller in the presence of uncertainties and external disturbance. The fuzzy online tune sliding function in fuzzy sliding mode controller is based on Mamdani's fuzzy inference system (FIS) and it has multi input and multi output. The input represents the function between sliding function, error and the rate of error. The output represents the dynamic estimator to estimate the nonlinear dynamic equivalent in supervisory fuzzy sliding mode algorithm. The performance of the AFSGSMC was compared with the IC engine controller based on sliding mode control theory (SMC). Simulation results signify good performance of fuel ratio in presence of uncertainty and external disturbance

Introduction

Modeling of an entire internal combustion (IC) engine is a very important and complicated process, because internal combustion engines are nonlinear, multi inputs-multi outputs (MIMO) and time variant. There have been several engine controller designs over the years in which the main goal is to improve the efficiency and exhaust emissions of the automotive engine [1]. Specific applications of air to fuel (A/F) ratio control based on observer measurements in the intake manifold were developed by Benninger in 1991 [2]. Another approach was based on the measurements of exhaust gases on the throttle position using the oxygen sensor, which was done by Onder [3]. Hedrick also used the measurements of the oxygen sensor to develop a nonlinear, sliding mode approach to control the A/F ratio [4]. All of the previous control strategies were applied to engines that used only port fuel injections, where fuel was injected in the intake manifold. Current production A/F ratio controllers use closed loop feedback and feed forward control to achieve the desired stoichiometric mixture. These controllers use measurements from the oxygen sensor to control the desired amount of fuel that should be injected over the next engine cycle and have been able to control the A/F very well [5].

In developing a valid engine model, the concept of the combustion process, abnormal combustion and cylinder pressure must be understood. The combustion process is relatively simple and it begins with fuel and air being mixed together in the intake manifold and cylinder. This air-fuel mixture is trapped inside cylinder after the intake valve(s) is closed and then gets compressed [6].When the air-fuel mixture is compressed it causes the pressure and temperature to increase inside the cylinder. In abnormal combustion, the cylinder pressure and temperature can rise so rapidly that it can spontaneously ignite the air-fuel mixture causing high frequency cylinder pressure oscillations. These oscillations cause the metal cylinders to produce sharp noises called knock, where it caused to abnormal combustion. The pressure in the cylinder is a very important physical parameter that can be analyzed from the combustion process. Since cylinder pressure is very important to the combustion event and the engine cycle in spark ignition engines, the development of a model that produces the cylinder pressure for each crank angle degree is necessary. A cylinder pressure model that calculates the total cylinder pressure over 720 crank angle degrees was created based upon the following formulation [6].

$$\boldsymbol{P_{cyl}(\theta) = P_m(\theta) + P_{net}(\theta)} \tag{1}$$

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Optimization Spring Coil Design for Orthodontic Tooth Movement

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Keywords: Optimum design, Spring Coil, Orthodontic.

Abstract. Orthodontic tooth movement is achieved by the remodeling of alveolar bone in response to mechanical loading by using spring coil. Spring coil design was made of round stainless steel wire and usually it was custom-made design. In the previous study, the orthodontic force on 30 gram is required to move maxillary incisor during experimental tooth movement in rat. In this study, optimization new design of spring coil is developed to fulfill the requirement of orthodontic force. The design variable of new spring coil design is set on variation of angle aperture ($5^o \leq \alpha \leq 10^o$), hook length (10 mm $\leq l \leq$ 20 mm) and hook diameter (0.012 inch $\leq D \leq$ 0.014 inch). From the result, it can be produced the optimum designs which 8.9^o of angle aperture; 12 mm of hook length and 0.014 inch of hook diameter for fulfilling the requirement of orthodontic force on 30 gram force.

Introduction

Orthodontic tooth movement is achieved by the remodeling of alveolar bone in response to mechanical loading [1, 2]. When force is applied to a tooth during orthodontic tooth movement by using spring coil, mechanical stress is loaded on the alveolar bone. Alveolar bone and the periodontal ligament (PDL) are compressed on one side, while on the opposite side, the PDL is stretched. Mechanical stress on the stretched PDL induces alveolar bone modeling (surface apposition of bone), while mechanical compression gives rise to bone remodeling [3, 4]. Spring coil design was made of round stainless steel wire and usually it was custom-made design. Fig. 1 shows Premaxilla placed in the acrylic pattern, in which the custom-made spring coil design is seen.

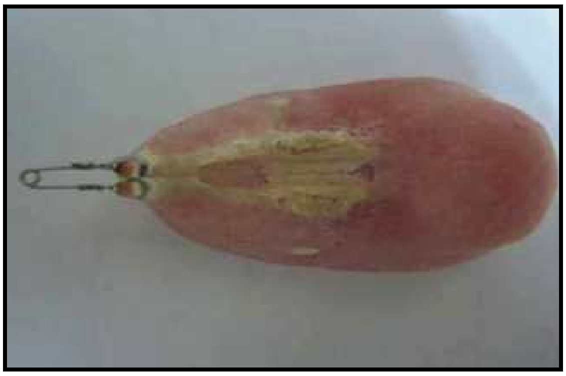

Fig. 1 Premaxilla placed in the acrylic pattern, in which the custom-made spring design is seen

The spring coil design is developed to fullfill the requirement of orthodontic force. Fig.2a shows one example of spring coil design which is a helical torsion spring. This spring was previously used by Storey (1973) and Stark and Sinclair (1987) and modified by Karadede (1992). The spring arms were 13 mm long with an angle of 70 degrees. In order to produce two different forces, 0.012 and 0.014 inch round stainless steel arch wires were used. The free ends of the springs were inserted into the holes in the incisor teeth. The residual ends were bent distally and cut in order to stabilize the springs in the mouth (Fig. 2b).