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Fault Diagnosis Based on Model and Dynamic Behavior of Vehicle Suspension System

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ABSTRACT: This research, proposes a new effective and practical method, based on the model and dynamic behavior of vehicles for accurate and fast fault diagnoses of their suspension system. So far, a variety of complicated and impractical algorithms have been presented to identify the suspension system faults. In this method, there is no need to use special equipment and tests to diagnosis the fault, in the event of fault appearance, whenever the vehicle passes over obstacles with a necessary excitation threshold such as a speed bumper, the user is alerted, accordingly the position and size of the fault are determined. Designing a suitable structure and using neural-fuzzy networks to identify faults plays an important role in reducing the error of fault diagnosis. Reducing the number, type of sensors (using only the accelerometer sensor), not relying on high sample rates, low-cost and easy to use are other advantages of the proposed method. The fault diagnosis system performance and implementation ability is verified and confirmed by designing and conducting different experiments.

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1- Introduction

The available published papers and researches in the field of vehicle fault detection can mainly be divided into two main branches: identification of faults in vehicles engine and other components (driveline, braking, steering and suspension). Suspension is a part of the chassis system which plays an important role in a vehicle's behavior and performance. Many intricate methods and algorithms based on analytical models, knowledge and data-based methods have so far been employed to identify and diagnose the suspension system's faults [1-5]. Although their accuracy is of an acceptable level in diagnosing faults, the complexity and obstacles existing in their practical implementation, requires using special and supplementary equipment and neglecting some parameters such as the effects of noise and disturbances, which lead to inefficiency and unpractical use of algorithms (false warnings and fault predictions). The effective and simple to use proposed method for fault diagnoses processes and analyses the signals received from acceleration sensors. The selection of appropriate and deterministic output signals, utilizing the least possible number of them to determine the parameters of a system with a relatively simple, accurate and cost-effective approach is considered as a major feature of this research.

2- Diagnosing Faults of the Suspension System

In the present research, the capability of neural networks in training and the ability of the fuzzy system in approximate reasoning, are utilized by employing the fuzzy-neural systems with fuzzy clustering techniques in the suspension system fault diagnosis process. The overall diagnosis process is divided into two main stages of training and testing. At the test stage (Fig. 1), the characteristic signs of the residual faults are considered as inputs, whenever these attributes are matched with a class of faults, the system output will specify a number representing the corresponding fault [6]. In practical situations, several faults or defects can be considered for the suspension system. However, in this study, with regard to the existing limitations, only three cases including shock absorber, springs and tires faults are investigated, when faults are considered as reduction of the damping rate, suspension springs stiffness and the tires air pressure, respectively. In order to achieve optimal performance and increase reliability of the proposed method, effective factors are investigated and optimal conditions for using the diagnostic system are determined. Simulation of the suspension system full model is carried using Matlab software.

3- Experimental Study

In real conditions, some factors, such as noise and disturbances, can prevent proper and on time detection of defects, so it is necessary to design and carry out practical tests and confirm the feasibility of implementing a fault diagnosis system in real conditions and ensuring its correct functioning, proper practical experiments have been designed and carried out. Fig. 2 shows the defected parts (spring and shock absorber) of the front suspension system. The type of test scenario in Fig. 3 is showing commonly used speed bumper on the road surface. Fig. 4 shows the position of accelerometer sensor and Fig. 5 the signals sample collected from accelerometer sensors in a healthy and faulty mode when the wheel has passed over a speed

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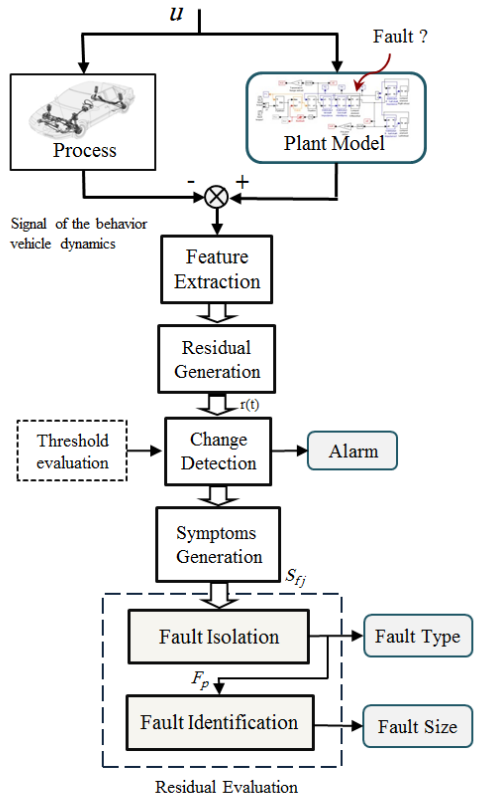
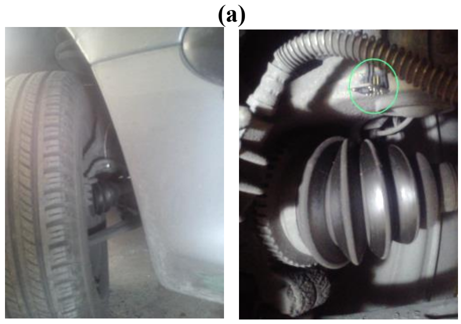


Fig. 1. Flow chart of the proposed FDD method

Fig. 2. Defected parts (spring and shock absorber) front wheel suspension

Fig. 3. Vehicle during test (Speed Bumper)

(a)



(b)

Fig. 4. Position of the accelerometers (a) on the body (b) close to the front wheel hub assembly

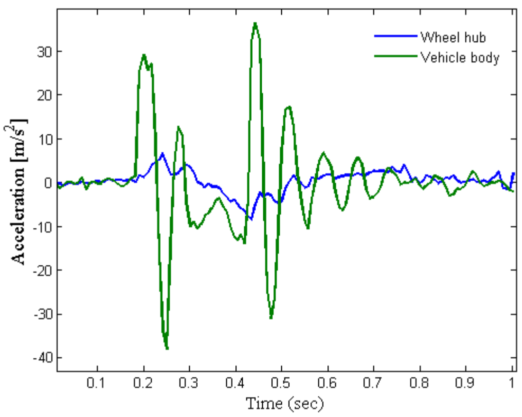
bumper. Table 1 shows the performance evaluation results of the proposed method for detecting the suspension system faults which are obtained from collected experimental data. As can be seen in the Table 1, despite error sources, including noise, disturbances, installation and measurement errors, low sample rates and other factors, the accuracy of the fault prediction by the proposed method is satisfactory. This proves capability of implementing the diagnosis system in practical situations.

4- Conclusions

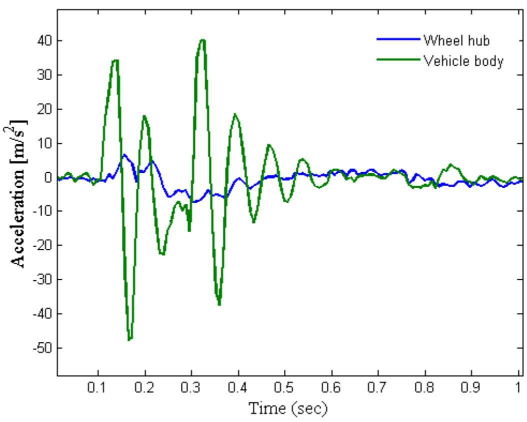
Receiving fault alerts, plus obtaining information about the position and size of defects in case existence, when the car passes from an obstacle with a necessary excitation threshold (a speed bumper), provides an innovative and

Table 1. Performance evaluation of the diagnostic method

Faulty type	No. of sample	No. of Correct diagnosis	No. of Wrong diagnosis	No. of Undiagnosed	Accuracy of detection
$F_{3,1}$	30	25	1	4	83 %
$F_{3,2}$	30	26	0	4	86 %
$F_{1,1}$	30	24	3	3	80 %
$F_{1,2}$	30	24	2	4	80 %



(a)



(b)

Fig. 5. The vertical acceleration signal of the wheel and vehicle body (front-right). a- healthy mode, b- faulty mode

effective solution to detect vehicle suspension system faults. Some more advantages of the proposed method are providing a new, simple and practical user friendly solution for the problem of fault detection. The proposed method has utilized the capabilities of fuzzy- neural network for an accurate and reliable diagnostic system while reducing the number and type of needed sensors and also benefitting from low cost.

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