British Journal of Applied Science & Technology
4(24): 3481-3491, 2014

SCIENCEDOMAIN *international*
www.sciencedomain.org

Failure Diagnosing in Vehicles Using Acoustic Emission

Ahmad Awad[1], Omar Badran[1], Mohammad Ghaith[1] and Anwar Al-Mofleh[2*]

[1]Department of Mechanical Engineering/Faculty of Engineering Technology Al-Balqa Applied University, P.O.Box (15008), North Marka, 11134, Amman, Jordan.
[2]Department of Electrical Engineering/Faculty of Engineering Technology Al-Balqa' Applied University P.O.Box (15008), North Marka, 11134, Amman, Jordan.

Authors' contributions

This study was jointly designed and carried out by the authors. All authors read and approved the final manuscript

Original Research Article

Received 8th April 2014
Accepted 4th June 2014
Published 27th June 2014

ABSTRACT

Aims: Two diagnosing faults of the vehicle's parts, an old and modern method, mechanical or electronic methods, before or after faulty occurring, One of methods which can be used before faulty occurring is Acoustic Emission (AE) for parts producing sound, this give an indication of the status of the part, and an expectation if the part is in good condition, needs repairing or replacing.
Study Design: Mention the design of the study here.
Place and Duration of Study: Department of Mechanical Engineering / Faculty of Engineering Technology Al-Balqa Applied University, P.O.Box (15008), North Marka, 11134
Amman - Jordan, between June 2012 and July 2013.
Methodology: The detection software of MATLAB V7 were used (i.e. For signal analyses and processing of the results), a Crystal Piezoelectric microphone (sensor has a sensitivity - 60 dc, 5 mv/pa/1KHz). Sound recorder program (from Jet Audio Program V7.6 for recording sound from microphone and save it on a computer with wav file). Band pass filter (for filtering sounds which we recorded at a certain range of frequency of about 100-20000 Hz).
Results: In this work, it was observed and concluded that the sound of the faulty parted

**Corresponding author: E-mail: anwaralmofleh@yahoo.com;*

has frequency fluctuation higher than frequency fluctuation of good part. In a similar trend found in the energy of sound, where the sound level of the faulty part is found to be much higher than the sound level of the good part. Hence, a healthy monitoring of the huge mechanical system such as vehicles and industrial machines can be achieved as a non destructive testing (NDT).

Conclusion: The experimental and theoretical study in this project has been proven to be successful for the failure prevention for vehicle components by the combination of acoustic emission properties and a written code using MatLab software besides using very simple inexpensive signal collector.

Keywords: Diagnosing; vehicles; acoustic; emission.

1. INTRODUCTION

Each transport company manages a fleet of vehicles, usually in a different technical condition. This condition greatly affects the readiness and vehicle productivity. It can also be translated into a certain level of transportation services and a defined level of customer satisfaction. Technical diagnostic vehicles are performed based on the technical characteristics of their status, such as the maximum speed, fuel consumption, the compression pressure. Several authors [1-3] have shown that certain certain individuals may be more useful than others and accept that we cannot predict a priori which of them are most important in a particular analytical process. Thus, the discovery of the importance of practical diagnostic and informational capacity of the particular characteristics is essential for the efficiency and effectiveness of the process of technical analysis [1,4,5] another important issue in vehicles diagnostic technique is defining the limits of the characteristic values. There are several regulations and standards as well as service manual that determine acceptable levels of the boundaries (boundary points) divide the range of values of the trait in a number of intervals corresponding to concrete technical conditions of vehicles. If there are only two intervals of the classification has a binary character, for example, vehicles in good or bad technical condition.

If the number of intervals is the classification can be more flexible and different classes characterizing the technical condition of vehicles more accurately can be distinguished, for example, vehicles in excellent condition, requiring tune-up/maintenance, The relationship between the description of the individual vehicles using values of some characteristics and the (global) world ranking of vehicles is another question worth investigating. Find a correlation between these two classifications is an important factor influencing the design and implementation of technical analysis as well as fleet maintenance and management policies of the fleet. Although the technical realization of vehicle diagnostics can be treated with various types of individuality, Some of these criteria may be , namely the Some of these criteria may be, namely the preferences with ordered domains, for example the engine power, speed, fuel consumption, etc., and other attributes may be, that is to the characteristics of preferred shares without orderly areas such as: body color, model of vehicle, If at least one of the features is a criterion and object classes (vehicles) are in order of preference the problem classification becomes a sorting problem [6]. In addition, the diagnostic process may involve certain characteristics which are originally supplied in continuous ladder and others are discreet. Within each diagnostic technique of analytical tools, such as statistics [7-9] methods and prediction methods [10] and optimization techniques [11] can be applied. In recent years, many authors have reported a successful application of artificial intelligence tools lack of technical diagnostics of vehicles and other technical objects [12]. Have developed a test system of neural network based diagnostic for shock absorbers of the armored vehicle. They defined diagnostic features and data necessary to determine the state of a shock absorber. The main objective of this research is to find the best and easiest way to diagnose the condition of vehicle parts conclude whether these parts should be replaced or not, and in which state it is.

2. EXPERIMENT SETUP

Detection software MATLAB v 7 were used (for the analysis and processing of the results of signal), a piezoelectric crystal microphone (sensor sensitivity - 60 cc, 5 mv/pa/1KHz). Sound recording program (Jet Audio V7.6 program to record sound from microphone and save it on the computer with the wav file). Low-band filter (filter for sounds that we have registered at a frequency range of about 100 to 20000 Hz).

2.1 Experimental Procedures

At the first installation of our software, for the preparation the program sound recorder from entertainment folder in Windows programs, after turning the filter used the laptop to record the necessary signals. Sound recording program can record recorded by the microphone in the specified folder in the computer sounds. Next step, connected the acoustic sensor, microphone to the computer, as shown in Fig. 1 and then got the noise effect of the registration process. During the test, Different engines where used (Tables 1 and 2) and during the test the engines must be running and is expected to reach operating temperature (80-90ºC), after that one can verify the targeted parts. Recording the sound of the defective parts of the vehicle is an essential part; so that sound will be recorded in a folder created for the vehicle. The sound that needs to check the part is imported into the MATLAB program for the selected type of vehicle. Then the program will compare the recorded sound with good part (not defective part) thereof, to see the difference between them. From this analysis, one can know if the part must be repaired or not. Or if the part needs maintenance or replacement, the repair technicians will replace it. After repair, there is need to verify the effectiveness of the maintenance process by recording the sound of the new part to compare it with the good part signal. If the difference between the two signals is almost matched it shows that we have a good effectiveness of the repair and if the difference is high, we must repair the new part and replace it with another, then test it again.

2.2 Matlab Programming

The library of data using MATLAB is used as reference data for all vehicles with interface to easily reach the data and to quickly compare them. Before the open order, there is a need to save the recorded file in the special vehicle program. Then Program MATLAB open library and open the program and save it as a good acoustic emission referred to the good parts. In the next step, the recorder import the data saved as reference. Before commencing the test one must select the vehicle manufacturer, then select model of vehicle and the part to be tested and what is the speed of the test as shown in Figs. 2 and 3.

After that, two pictures appear, first picture gives information about time domain and second picture gives information of frequency domain as shown in Fig. 4.

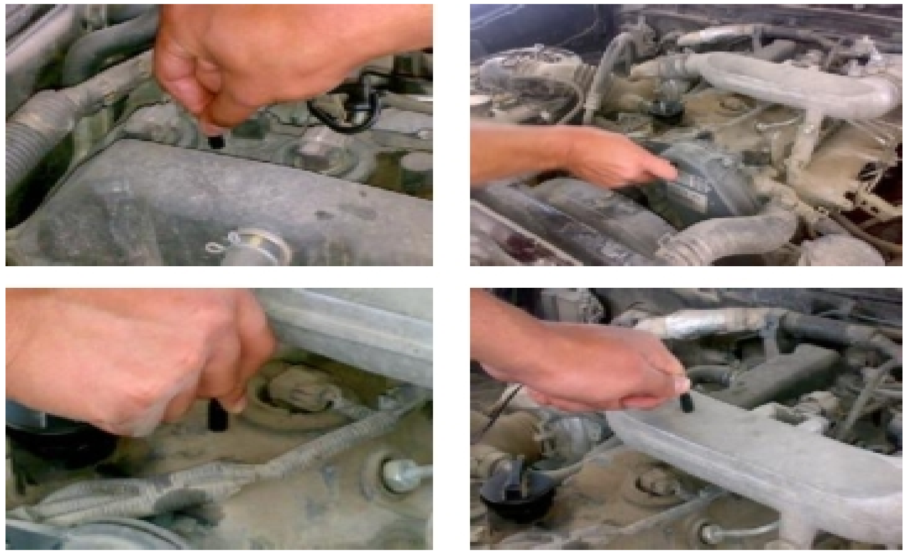
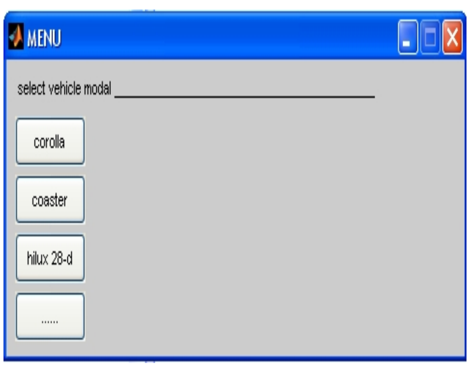


Fig. 1. Selected position



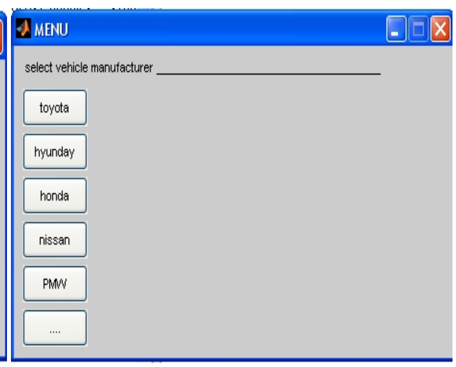


Fig. 2. Select vehicle manufacturer **Fig. 3. Select vehicle model**

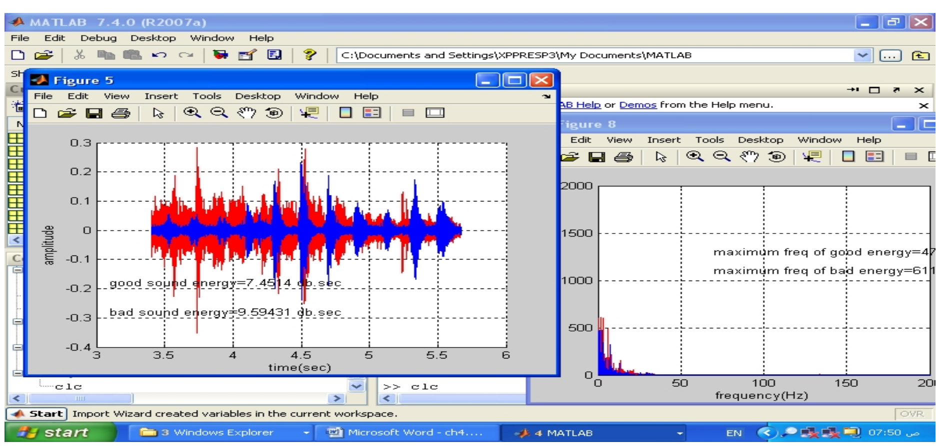


Fig. 4. Results (where blue is good part, red is a faulty part)

3. RESULTS AND DISCUSSION

3.1 Toyota Coaster Testing Analysis Results

In Fig. 5 one can see the difference between good and faulty sound. The sound level for good part (blue) equals to (2.00624 dB), but the sound level for faulty parts (red) equals to (2.75137 dB) increasing by 37% from the good part sound level. In Fig. 6 one can see the difference between good peaks(blue) and faulty peaks (red) and frequency fluctuation for the better part equals to (1.78659KHz), but in faulty part equals to (1.98682KHz). Hence, the frequency fluctuation for faulty part is higher than that for a good part with 11%.

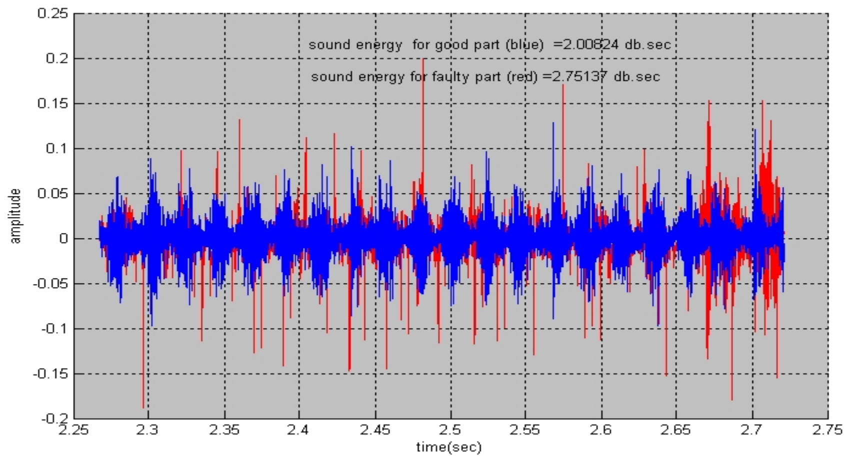


Fig. 5. Valve sound in time domain at 1200 rpm

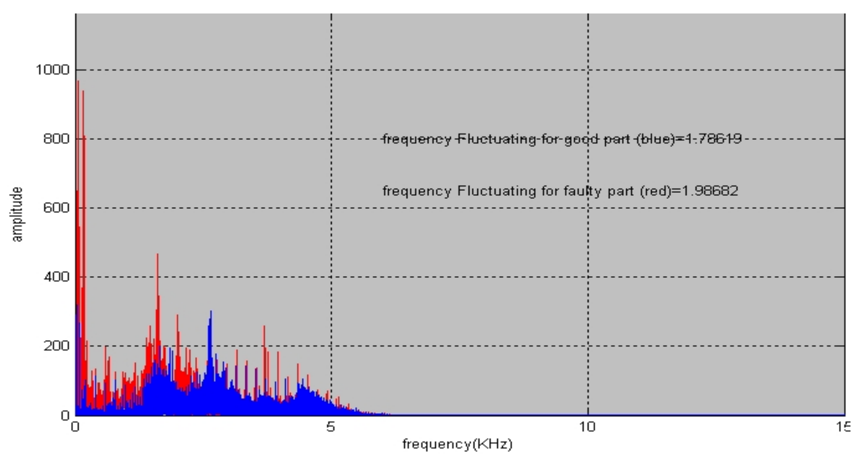


Fig. 6. Valve sound in frequency domain at 1200 rpm

3.2 Toyota Hilux Testing Analysis Results

In Fig. 7, one can see the difference between good and faulty sound at 800 RPM, the sound level for the good part (blue) equals to (1.71 dB), but sound level for faulty parts (red) equals to (2.598 dB) increasing by 52% of good part sound level . In Fig. 8, it can be seen that the difference between good peaks (blue) and faulty peaks (red) and frequency fluctuation for the better part equals to (1.706KHz), but in faulty part equals to (1.9924KHz), then the frequency fluctuation for faulty part is higher than that for the better part by 14%. In Fig. 8, we can see that the difference between good and faulty sound at 2000 RPM , the sound level for good part (blue) equals to (97.85 dB), but sound level for faulty part (red) equals to (667.55 dB) increasing by 582% of the good part sound level . In Fig. 9, it can be seen that the difference between good peaks (blue) and faulty peaks (red) and Frequency fluctuates for the better part equals to (2.0114KHz), but in faulty part equals to (2.2122KHz),then the frequency fluctuation for faulty part is higher than that for good part by 10% as shown in Table 1. From the above Figs. (7-10)) it is clear that when running the speed increases, the amount of sound level and frequency fluctuation are significantly increases. This in turn will be more dangerous at high rpm's and the noise can be distinguished clearly.

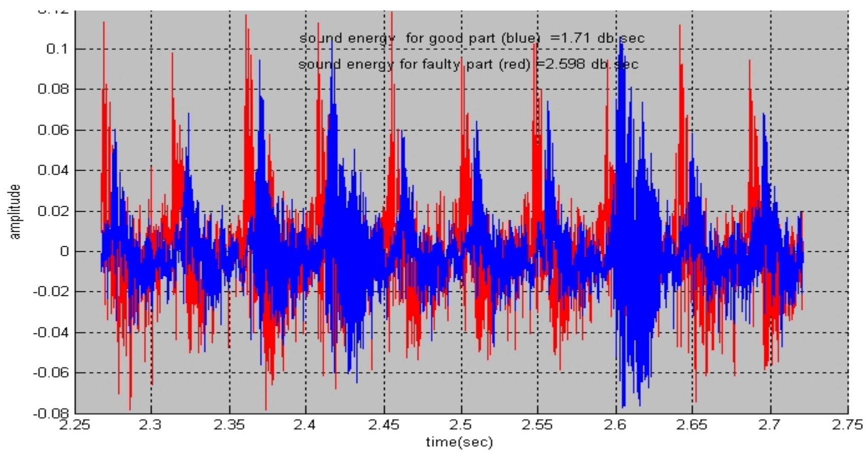


Fig. 7. Engine injectors sound in time domain at 800 rpm

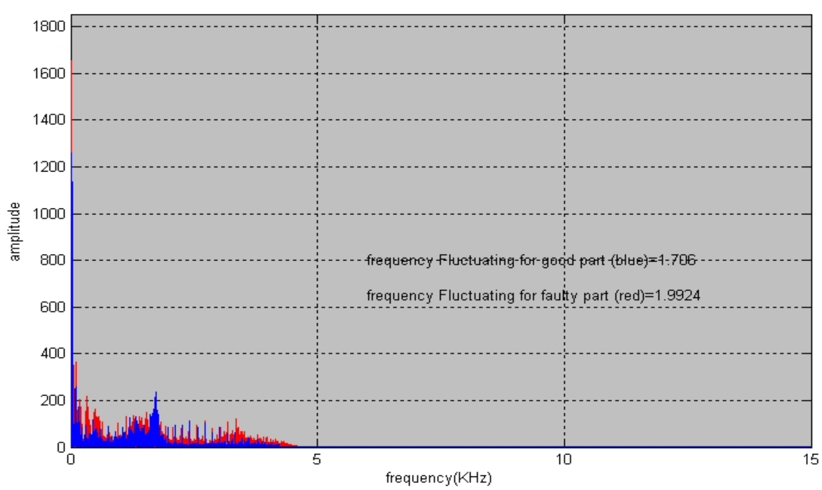


Fig. 8. Engine injectors sound in frequency domain 800 rpm

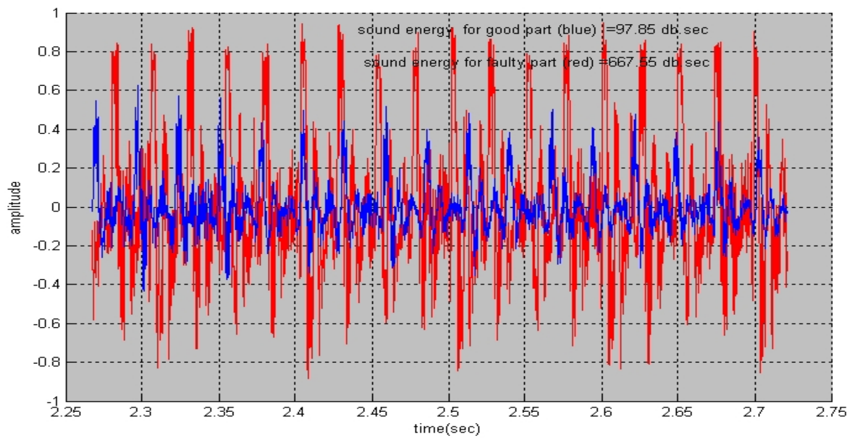


Fig. 9. Engine injectors sound in time domain in 2000 rpm

3.3 Toyota Corolla 2006 Analysis Results

In Fig. 11, can see the different between good and faulty sound in 750 RPM, the sound level for the good part (blue) equals to (10.48 dB), but sound level for faulty parts (red) equals to (71.94 dB) in an increasing of 586% of the good part sound level . In Fig. 12, can see the difference between good peaks (blue) and faulty peaks and frequency fluctuating for the better part equals to (1.349KHz), but in faulty part equals to (1.508KHz).Hence the frequency fluctuation for faulty part is higher than that for a good part with 12%. In Fig. 13 , can see the different between good and faulty sound in 1200 RPM , the sound level for the good part (blue) equals to (139.24 dB), but sound level for faulty parts (red) equals to (521.73 dB) in an increasing of 275% of the good part sound level. In Fig. 14, can see the difference between good peaks(blue) and faulty peaks (red) in 1200 rpm and Frequency fluctuates for the better part equals to (1.4608KHz), but in faulty part equals to (1.5104KHz).Hence the frequency fluctuation for faulty part is higher than that for good part with 3%. In Fig. 15, can see the different between good and faulty sound in 1700 RPM, the sound level for the good part (blue) equals to (181.26 dB), but sound level for faulty parts (red) equals to (673.87 dB) in an increasing of 272% of the good part sound level . In Fig. 16, can see the difference between good peaks(blue) and faulty peaks (red) in 1700 RPM and Frequency fluctuates for the better part equals to (1.5292KHz), but in faulty part equals to (1.6432KHZ). Hence, the frequency fluctuation for faulty part is higher than that for a good part with 7% as shown in Table 2. From the Figs. 11 to 16, it is clear that when running the speed increases, the amount of sound level and frequency fluctuation are significantly increases. This in turn will be more dangerous at high rpm's and the noise can be distinguished clearly.

Table 1. Toyota Hilux testing results (Injectors)

Speed (rpm)	Sound level for good part (blue)	Sound level for faulty part (red)	Sound reduction	frequency Fluctuating for good part (blue)	frequency Fluctuating for faulty part (red)	Frequency reduction
800	1.71 dB	2.598 dB	52%	1.706	1.9924	14%
2000	97.85 dB	667.55 dB	582%	2.0114	2.2122	10%

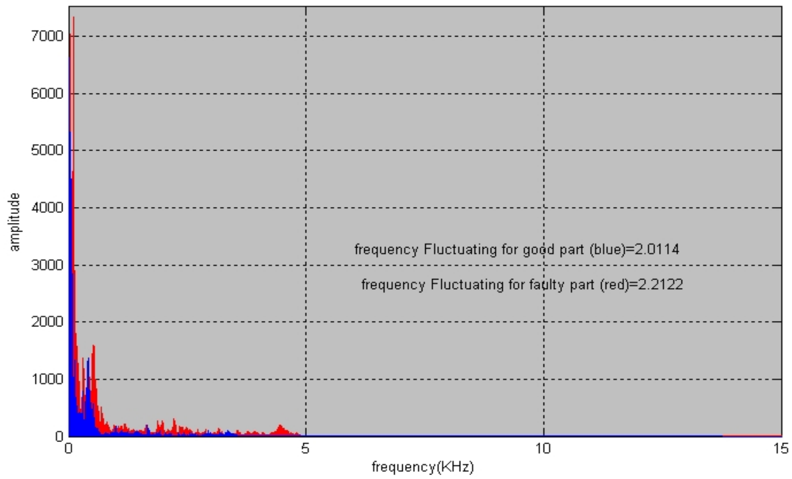


Fig. 10. Engine injectors sound in frequency domain at 2000 rpm

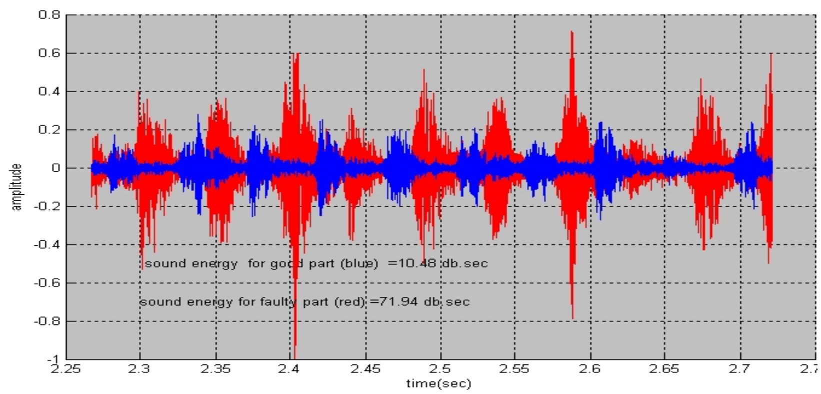


Fig. 11. Engine sound at time domain at 750 rpm

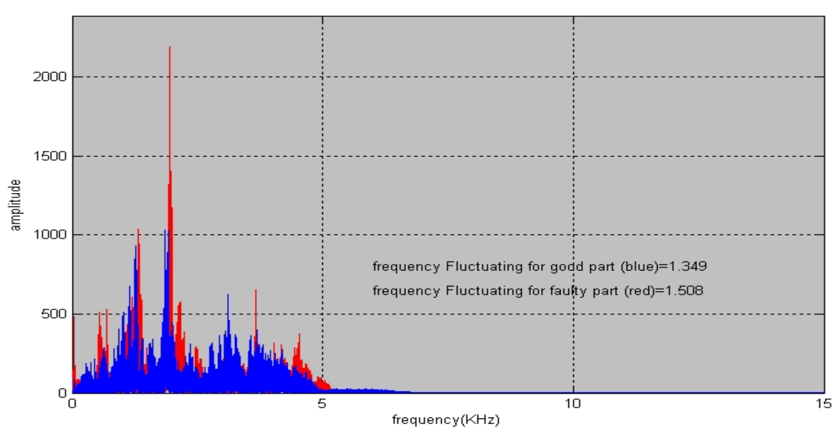


Fig. 12. Engine sound at frequency domain at 750 rpm

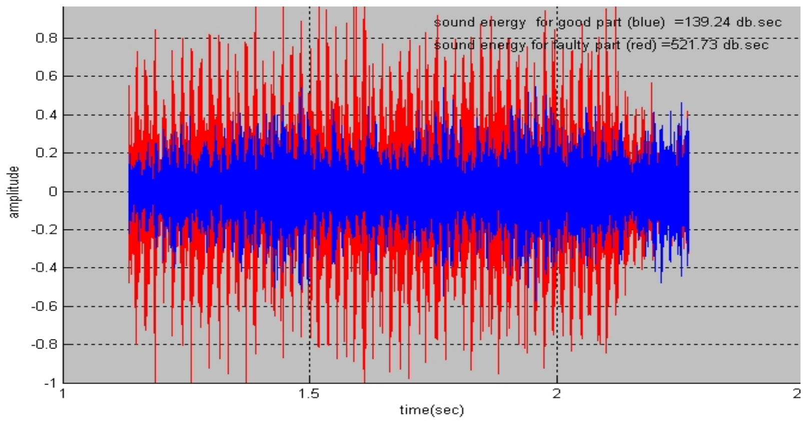


Fig. 13. Engine sound at time domain at 1200 rpm

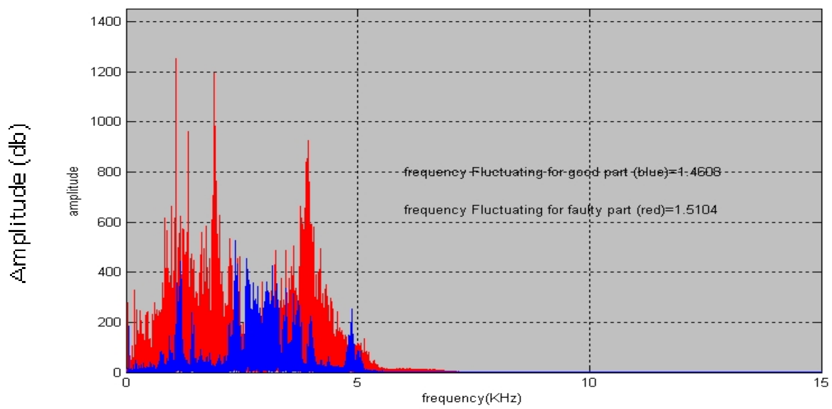


Fig.14. Engine sound at frequency domain at 1200 rpm

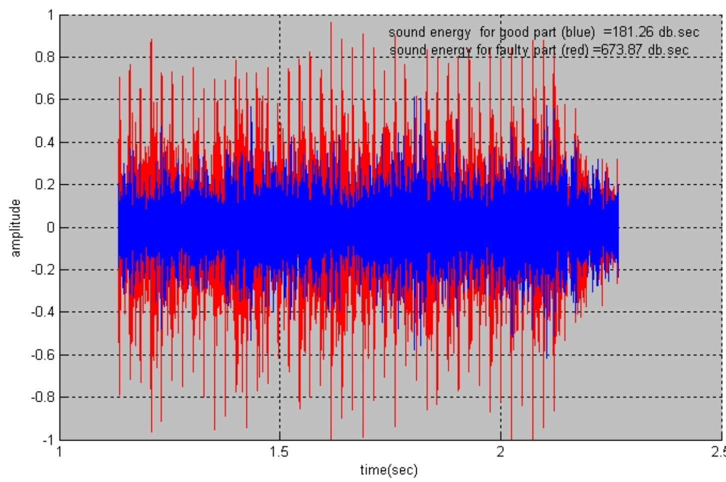


Fig. 15. Engine sound at time domain at 1700 rpm

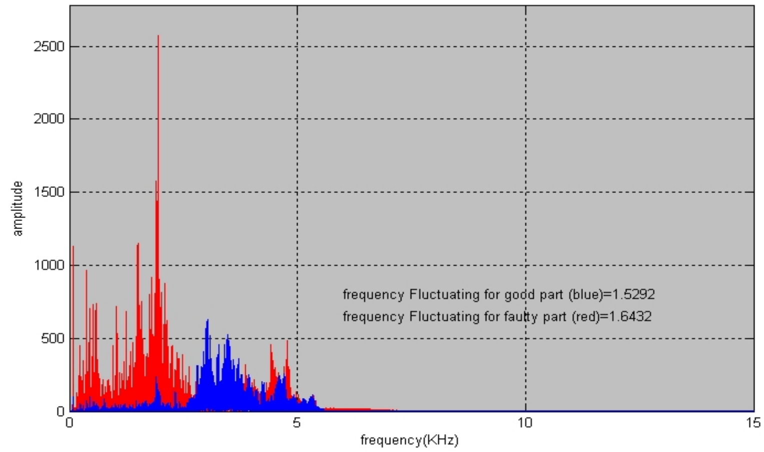


Fig. 16. Engine sound at frequency domain at 1700 rpm

Table 2. Toyota corolla testing results

Speed (RPM)	Sound level for good part (blue)	Sound level for faulty part (red)	Sound reduction	Frequency fluctuating for good part (blue)	Frequency fluctuating for faulty part (red)	Frequency reduction
750	10.48 dB	71.94 dB	586%	1.349	1.508	12%
1200	139.24 dB	521.73 dB	275%	1.4608	1.5104	3%
1700	181.26 dB	673.87 dB	272%	1.5292	1.6432	7%

4. CONCLUSION

The present experimental study showed that predicting the failure of vehicle components by acoustic emission and using MatLab software code is very simple and effective method for diagnosing vehicle engine parts In this work, the following conclusions can be obtained:

1. Sound level signal is a good indicator of the state of the engine party.
2. Analysis of sound level gives an indication of any faulty in engine various parts.
3. The sound level coming from good and bad parts can estimate the degree of impairment.
4. Although the new party Acoustic Emission (AE) but with a minimal sound level.
5. The peaks of faulty parts are higher than the good part peaks in the frequency spectrum.
6. As engine RPM increases, the acoustic level will increase.
7. It can be seen that amount of sound level depends on two conditions, the first condition is the speed of the engine (extrusive relationship), and the second condition is the amount of defective part wear (the extrusive relationship)

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Zak J, Stefanowski J. Determining maintenance of motor vehicles using rough sets approach. In: Conference Proceedings, Euro maintenance' 94, Amsterdam. 1994;39–42.
2. Zak J. The application of rough sets theory in the fleet management of transportation companies. In: Proceedings of the 11th Mini Euro Conference: Artificial Intelligence in Transportation Systems and Science. Helsinki, article LIII; 1999.
3. Zak J, Sawicki P, Redmer A. Application of rough sets theory to the management of tram cars. In: Conference Proceedings: Traffic Management in the Cities under Congestion. Poznan. 1999;1:280–288.
4. Kelley A, Harris M. Management of industrial maintenance. London; 1987.
5. Sawicki P. Quality evaluation method of transportation system using rough sets theory. Doctoral dissertation, Warsaw University of Technology, Warsaw; 2003.
6. Słowinski R. Rough set learning of preferential attitude in multicriteria decision making. In: Komorowski J, Ras Z, (Eds.). Methodologies for intelligent systems. Lecture Notes in Artificial Intelligence. 1993;689:642–651.
7. Campbell JD, Jardine AKS. Maintenance excellence – optimizing equipment life-cycle decisions. Marcel Dekker, New York; 2001.
8. Caplen R. A practical approach to reliability. Business Books Limited, London; 1972.
9. Ilyakhinskii AV. Statistical approach to diagnostics of structures on the basis of acoustic emission signals. NDT & E International. 1992;25(6):294–297.
10. Isermann R. Process fault detection based on modeling and estimation methods a survey. Automatica. 1984;20(4):387–404.
11. Stoustrup J, Niemann HH. Fault estimation – a standard problem approach. International Journal of Robust and Nonlinear Control. 2002;12(8):649–673.
12. Sincebaugh P, Green W. A neural network diagnostic test system for armored vehicle shock absorber. Expert Systems with Applications. 1996;11(2):237–244.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history.php?iid=580&id=5&aid=5101