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A STUDY OF ACOUSTIC EMISSION INTENSITY EFFECT DURING FUEL INJECTOR FAULT

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ABSTRACT

Engine condition monitoring is one of the preventive actions that keep the performance of an engine at the top range. One of the nondestructive testing; Acoustic Emission Technique, offers an effective ways to detect the engine fault without dissemble the engine. This paper presented a study of Acoustic Emission intensity produced by fuel injector fault during engine running under idle condition. The experimental work was carried out on a four cylinder petrol engine. An Acoustic Emission device; AED-2000V Virtual Instrument was used to acquire the emitted signals. All data was recorded and analyzed to see the ratio between good and fault fuel injector condition. It can be concluded that the ratio was in the range of 0.1 to 0.2 and significant as an early indicator of fuel injector malfunction.

Keywords: Acoustic emission method; condition monitoring; automotive engine

INTRODUCTION

Engine performance monitoring and fault detection is vital in automotive engineering to ensure long lifespan of an engine. This situation stimulated the acquisition of vast amount of information using the most modern data acquisition method (Azzoni et al, 1998). If the data is used properly the performance of engine can be well monitored and also can detect the fault occurs in the engine to keep the engine at high performance. Hence, to avoid serious damage to the internal parts of the engine, the condition monitoring and fault diagnosis in a mechanical system is highly necessary (Wu & Liu, 2008).

Acoustic Emission Technique

Acoustic Emission is the released of stress energy from a material in form of transient elastic waves (Li, 2002). Acoustic emission technology is used in current non-destructive testing and also can be use as quality control in the manufacturing industries for a long time (Karpuschewski et al, 2000). A major advantages of using the Acoustic Emission Testing is that the frequency of machine vibrations or environmental noises does not interfere with the signal because of it sensitive sense of signal. By locating the AE sensor directly to the inspected specimen under stress, any flaws and defects can be easily sensed due to the abnormalities of signal emitted. Piezoelectric transducer as an AE sensor will be used on the surface of the structure under testing for detection of the high frequency waves (Karpuschewski et al, 2000). The output of the signal produced will be amplified through a low-noise preamplifier and it can be filtered to remove any unwanted noise. The transient waves, next can be converted in digital signals and recorded for further signal processing analysis to get needed parameters.

Acoustic Emission Testing (AET) was widely used in various fields especially in condition monitoring and fault detection due to high efficiency to detect defect and flaw in materials. The implementations of AET in engine performance diagnosis were recorded previously by a few researcher such as Azzoni et al. (1998) in the study of engine noise from F1 engines (Azzoni et al, 1998); Noorul & Tamizharasan(2007), the study of AE signal produced by the compression ring in the engine and the fault detection in diesel engine by Amanda et al. (2000).

Signals Emitted From Engine

The engine itself becomes more complex to achieve the target of high performance. Engine design and car design were integral activities which almost all of the engine designers also designed cars. Engine is one of the most revolving technologies and all of the world class car manufacturers compete towards each other to design an engine with high performance. As mentioned in Azzoni et al (1998), an engine can give so much information just by using its sound emission and vibration from its mechanical work and it is easy to record the signal for fault diagnosis (Azzoni et al, 1998). In an internal combustion engine, the compression of piston in the cylinder block will create a mechanical work by combusting the mixture of air fuel in the chamber (Wu & Liu, 2008; Noorul & Tamizharasan,2007; Nuawi et al, 2008). The movements will create a huge amount of signal and frequencies which imitate the mechanical work of the engine (Wu & Liu, 2008; Noorul & Tamizharasan,2007). Other critical part such as the fuel injector, valve opening and camshaft also will provide signals during its operation, thus the behavior of the part whether it is in good condition or not, can be observed (Gill et al, 2000). As a NDT methods with high frequency range, AET can be a good monitoring and fault diagnose to the engine (Ibrahim & Larry, 2001; Othman et al, 2007). Usually, in testing, the AE sensor is placed on the cylinder head because it's near to the source of signal (Noorul & Tamizharasan,2007; Amanda et al. 2000; Nuawi et al, 2008; Nivesrangsan et al, 2007). Any major or minor fault in an engine must be avoided so it can avoid from unwanted critical damages (Fleming, 2001).

Fundamentally, the better the fault is detect and discovered it's create a more efficient engine monitoring and fault diagnosis (Sammy & Rizzoni, 1996). In the automotive world, the maintenance of engine must need to replace the damage parts and overhauls (Sammy & Rizzoni, 1996) but if we have a proper engine monitoring it can save the maintenance initial cost and keeps the engine lifespan to its maximum degree for great performance.

METHODOLOGY

The testing was carried out on a four cylinder petrol engine of a Proton Pesona's 16 valve DOHC Campro engine with 1597cc engine capacity in semi anechoic chamber at Noise, Vibration and Harshness laboratory, Universiti Malaysia Pahang. The single channel Acoustic Emission system (AED-2000V Virtual Instrument) was used to acquire the signal from the engine. Generally, the engine combustion chamber is one of the biggest parts of an engine in producing frequencies of vibration which leads AE signals to appear. Thus, the sensor must be placed as near as possible to the combustion chamber. The top surface of the cylinder head was chose as the contact surface of the sensor because of its flat surface and most reachable place to the AE sensor. The AE sensor is properly mount on the cylinder head and was greased to improve signal transfers from engine to sensor. In order to reach the operating temperature, the engine was left to run idle for a few minutes before starting the experiment. All equipment like the sensor, the AED-2000V Virtual Instrument, Carman Scan and the host computer that is required for this testing was calibrated to the engine and checked to make sure they are functioning well. The experimental arrangement can be viewed as in Figure 1.

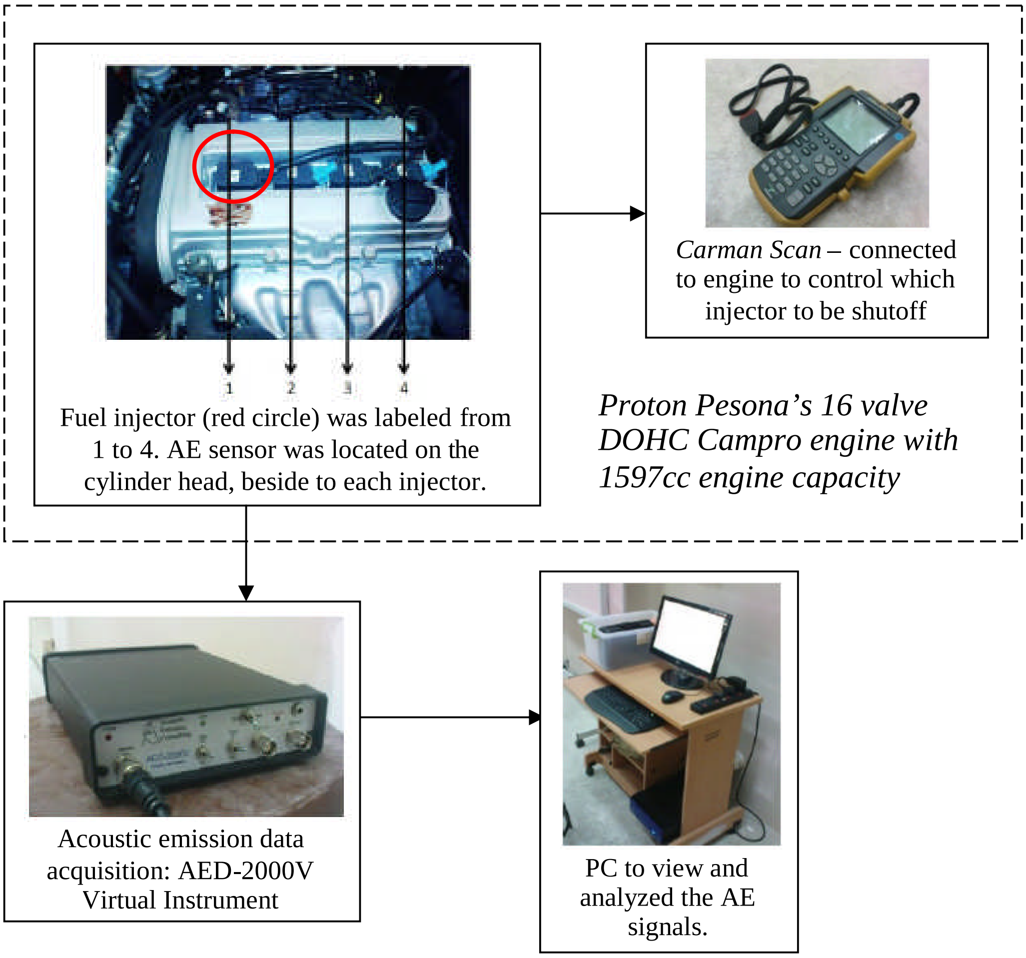

Figure 1: Experimental architecture

The fuel injector fault was initiated by activating the engine fuel injector shutoff button on the Carman Scan device. The AE sensor was placed at each cylinder (the engine have 4 cylinders) at different time. Only one injector was shut off at a time and AE signals were recorded at every cylinder. As for example, when fuel injector labeled 1 was turned off, AE signals were taken at cylinder 1 to cylinder 4 (engine cylinder was labeled the same as fuel injector). The engine ran at idle condition for 60 seconds then the fuel injector shutoff start for 60 seconds. The testing procedure is repeated by shutting off the fuel injector number 2, 3 and 4.

RESULTS AND DISCUSSION

Fuel injector is used in the internal combustion engine for more accurate fuel consumption. Direct fuel injector used as fuel delivery technology that allow gasoline engine to burn fuel more efficiently and to provide engine with a combustible air-fuel mixture. The position of the fuel injection system is near the intake valve in the combustion chamber. Nowadays, fuel injection system is electronic controlled like ECM so if there are fault occur, the ECM will calculate the fuel consumption which can make the engine operate at idle condition. The experimental results can be viewed as Figures 2-5.

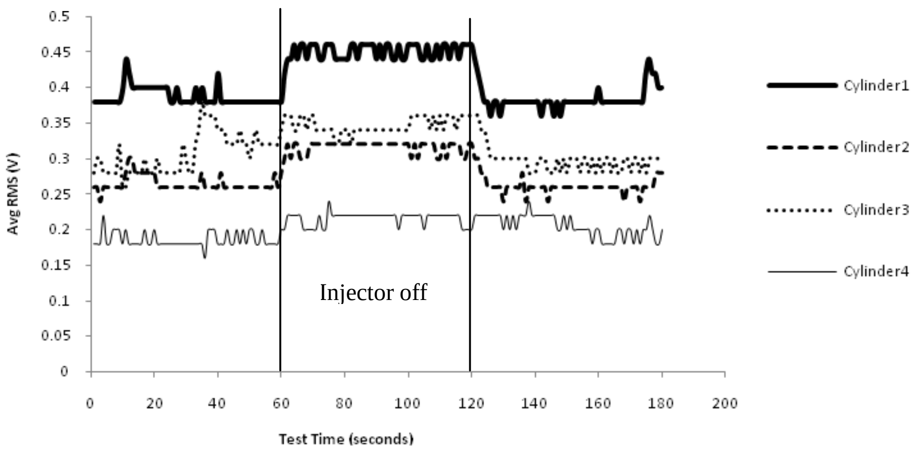

Figure 2: Fuel injector 1 turned off.

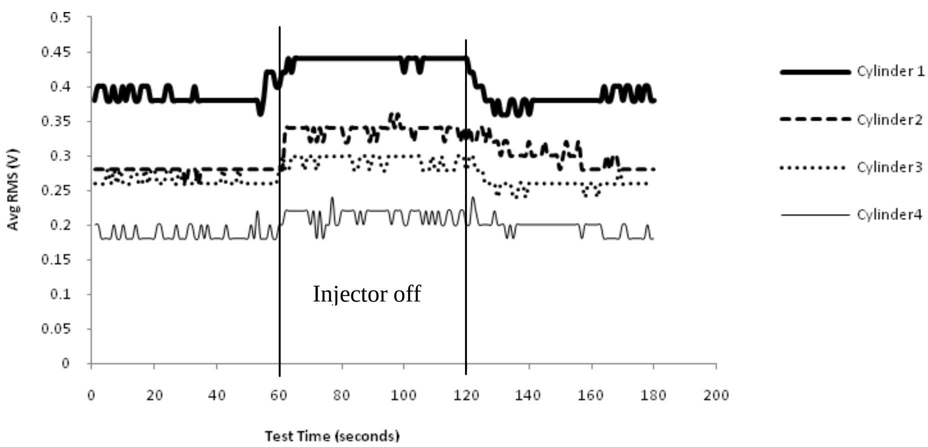

Figure 3: Fuel injector 2 turned off.

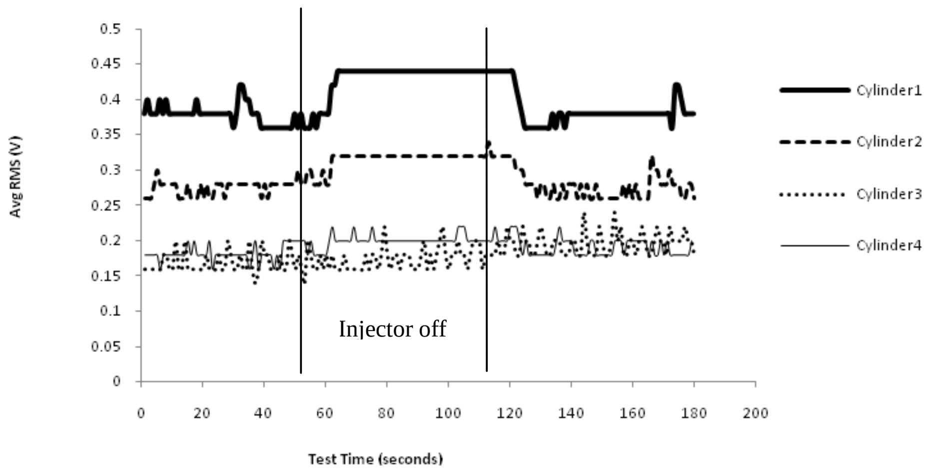

Figure 4: Fuel injector 3 turned off.

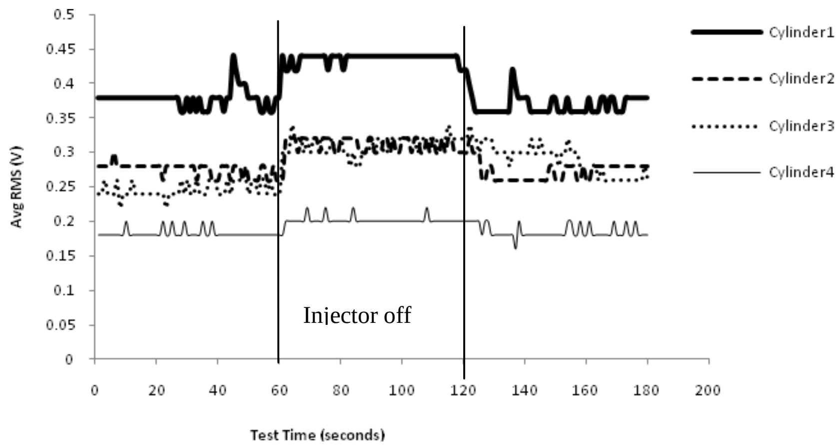

Figure 5: Fuel injector 4 turned off.

During the fuel injector shutoff, the torque in the engine is higher due to one of the piston is at state of dysfunction. The piston is bind by one crankshaft and operates simultaneously. This will make the engine work harder than before and leads to higher Root Mean Square (RMS) value for Acoustic Emission signals compared to normal condition (Figure 2 – 5). This phenomenon occurred due to the load of an engine is proportional to the signals produced (Noorul and Tamizharasan, 2007). The ratio between the increment of RMS values when injector shut off and the RMS values at normal condition can be concluded in Table 1.

Table 1: RMS ratio.

Fuel injector (shut off)	(Ratio = $RMS_{increment} / RMS_{normal}$) Cylinder 1	Cylinder 2	Cylinder 3	Cylinder 4
1	0.184	0.192	0.138	0.167
2	0.158	0.179	0.115	0.105
3	0.158	0.185	0.094	0.111
4	0.158	0.148	0.250	0.111

CONCLUSION

The results shown give a potential usage of AE technique to monitor and detect the fuel injector fault or other engine malfunctions. Note that the higher number of sampled signal and longer time for signal recording will indicate more accurate result. It can be concluded that the objective of this study has been achieved. Future enhancement of this research includes the inclusion of more faulty parts to be correlated with AE data and the AE signals will be analyzed using different other parameters.

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