20th International Conference
ENGINEERING MECHANICS 2014
Svratka, Czech Republic, 12 – 15 May 2014

AUTOMOTIVE PIEZOELECTRIC SENSORS FOR SIMPLIFIED KNOCK DETERMINATION

A. Aromiński*

Abstract: *A phenomenon of engine knocking is observed when a portion of the air-fuel mixture inside combustion chamber self ignites. Analyzing vibration signal from the flat response piezoelectric sensor located on cylinder block is one of the most popular method that provides sufficient accuracy in knocking determination. Knock sensors used in almost all modern gasoline engines can deliver a signal that is correctly interpreted by an engine control unit (ECU). This is possible due to the research and experience of manufacturers. This paper briefly presents a preliminary concept of using simple, relatively inexpensive automotive piezoelectric knock sensors to determine knock combustion phenomenon in prototype internal combustion engine. Initial" flat response" sensors tests without external amplification devices were conducted. Future research is expected to determine the actual range of using cars sensors for serious measurements.*

Keywords: Knock detection, Piezoelectric sensors, Internal combustion engine.

1. Introduction

Engine knocking is a phenomenon in which a portion of the air-fuel mixture inside combustion chamber self ignites. During that process, significant pressure increases and instabilities can be observed. Due to pressure waves, the cylinder block is likely to vibrate, usually in the 3-10 kHz frequency range (Bernhardt et al., 1988). The characteristic sound known as "knocking" or "pinging" can be observed. Optimal engine efficiency can be obtained near the threshold point of knocking, yet excessive knocking can decrease fuel economy, power output, and even lead to engine failure. It is therefore critical to determine whenever knocking occurs or false signals from various engine mechanical systems were acquired (Kiencke & Nielsen, 2005; Teichmann et al., 2012).

Analyzing the signal from the flat response piezoelectric sensor located on cylinder block seems to be the most popular solution that provides sufficient accuracy. Engine sensitivity to the appearance of knocking varies as a function of engine load and speed (Taylor, 1985). Knock sensors used in almost all gasoline engines can deliver a signal that is correctly interpreted by an engine control unit (ECU). This is possible due to the research and experience of manufacturers. Though a designer building a new prototype engine is at the beginning of a long road, the designer must determine the method of establishing bench measurements to be risk-free for the engine itself. This paper addresses some preliminary concepts of using typical sensors to determine knock phenomenon while not using an engine's ECU. It is not a vibration measuring method; instead, it is a simplified and relatively inexpensive solution to make bench tests safer for a prototype engine without incurring excess expenses.

Almost the same situation appears while testing changes in ignition systems, while testing electronic spark advance circuits, and while developing new fuel mixtures (Orliński, 2013). It is not possible to determine fuel anti-knock features while using original closed-loop ignition system of type found in production cars.

2. Components Description

At the beginning of test, two different models of "flat response" piezoelectric sensors from one manufacturer (NTK) were obtained. There was a significant time interval (more than 6 years) between

* Andrzej Aromiński, MSc.: IPBM Warsaw University of Technology, Narbutta 84, 02-524 Warsaw, Poland, andrzej.arominski@simr.pw.edu.pl

production dates of the sensors. Both sensors were mounted on a steel plate and appropriate tightening torque was applied.

A precise data acquisition system with a sampling rate of 100 kS/s per channel and hi-input impedance greater than 10 MΩ was implemented. A professional actuator for further detailed testing of frequency response was selected.

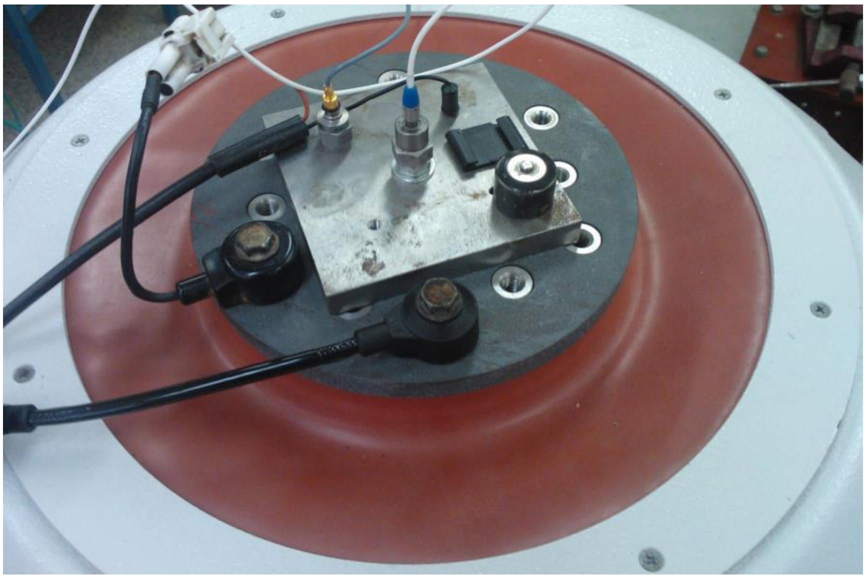

Fig. 1: Piezoelectric sensors mounted on actuator.

3. Measurements

Initial tests were conducted without any external amplifiers. Only excessive voltage protection was applied to the data acquisition system. As stated above, production date and sensor models were different but initial testing revealed that the piezoelectric element utilized in both was likely to be the same. Minor differences could be related to the unequal sensor distance from excitation force source, manufacturing tolerance, etc.

Fig. 2 represents voltage versus time response to impulse excitation; no signal conditioning algorithms were applied. Amplitudes up to 3 V were observed.

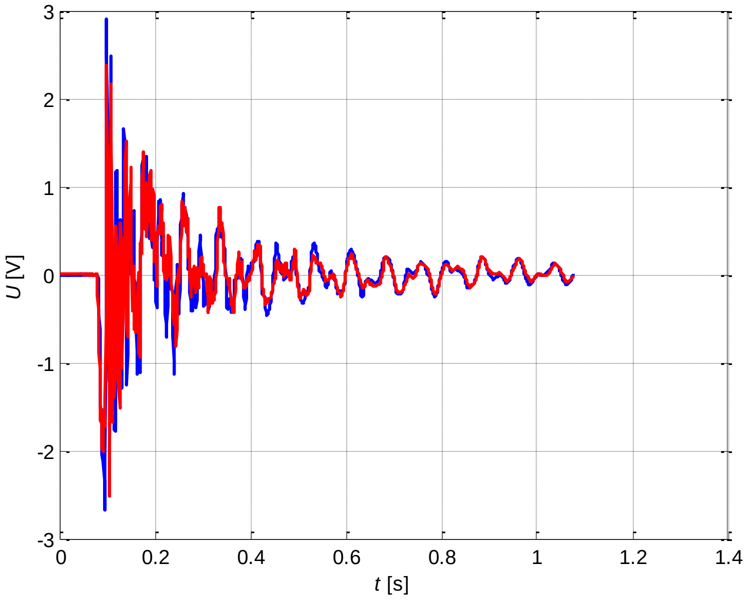

Fig. 2: Voltage over time diagram. Impulse response, no amplification.

A Fast Fourier Transform algorithm was used to determine voltage amplitude at desired frequency range.

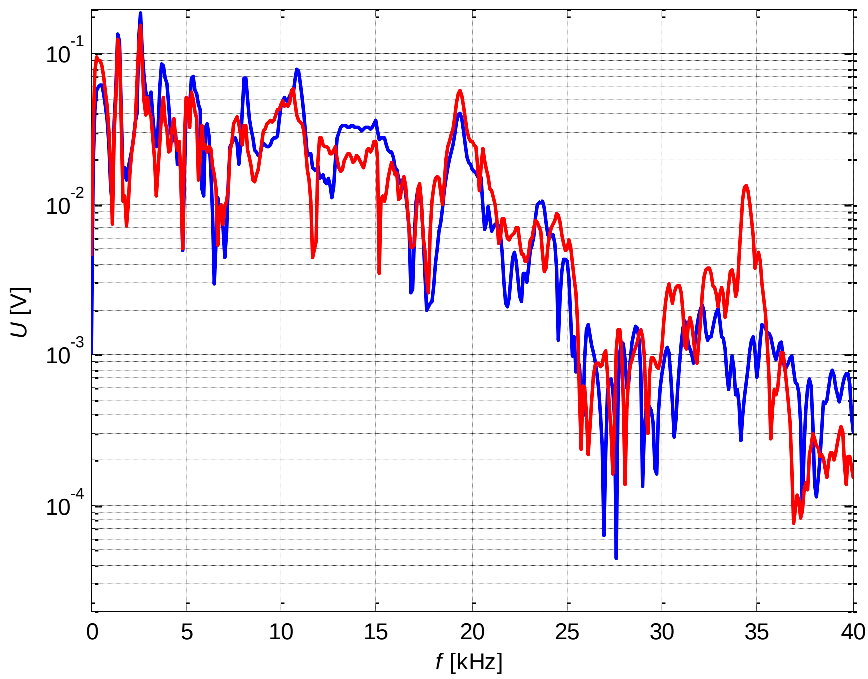

Fig. 3: FFT, semilogarytmic scale, frequency range 0-40 kHz.

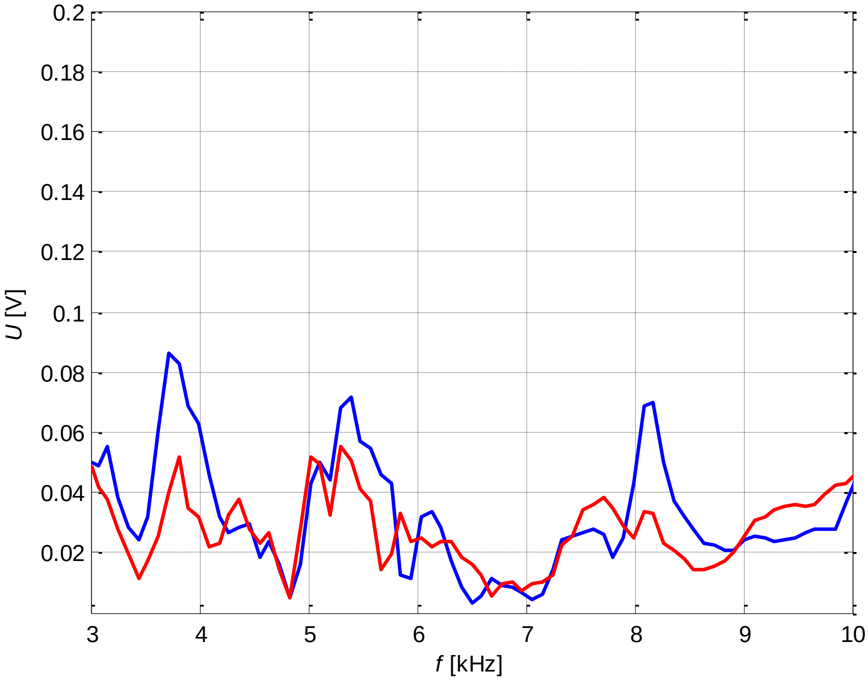

Fig. 4: FFT, linear scale, frequency range 3-10 kHz.

4. Conclusions

Conducted tests have shown that from the point of view of the knock phenomenon, voltage signal amplitude in a function of frequency is relatively small.

In the case of laboratory measurements, such a situation is acceptable. However, in the case of measurements conducted with a real engine, signal noise associated with the proximity of the ignition system components can significantly exceed the amplitude of the input signal. Moreover, the resolution of 10-bit combined with +/- 5V range of A/D converters commonly used in the aftermarket automotive industry is insufficient for accurate analysis of a unamplified vibration signal.

Several other measurement methods based on operational amplifiers in various configurations (non-inverting voltage amplifier, charge amplifier) were examined as a preface to investigating further phenomenon. Utilizing automotive sensors that are used in cars is an inexpensive and comfortable solution; however, utilizing such sensors as scientific measurement tools can at best lead to misunderstandings.

Future research is expected to determine the actual range of using cars sensors for serious measurements.

References

Bernhardt, M., Dobrzyński, S., Loth, E. (1988) Automotive engines. WkiŁ, Warsaw (in Polish).

Kiencke, U., Nielsen, L. (2005) Automotive Control Systems, Springer.

Orliński, P. (2013) Selected aspects of combustion process of biodiesel fuels. Wyd. Instytut Naukowo-Wydawniczy "SPATIUM", Radom (in Polish).

Teichmann, R., Wimmer, A., Schwarz, C., Winklhofe, E. (2012) Combustion Engines Development pp. 39-117, Springer.

Taylor, C. (1985) Internal Combustion Engine in Theory and Practice: Vol. 2 - 2nd Edition, The MIT Press.