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[1.] Orlin STOYANOV

DEVELOPMENT AND TESTING A DIESEL ENGINE DIAGNOSTIC SYSTEM

[1.] UNIVERSITY OF RUSE, BULGARIA

ABSTRACT: The purpose of this study is to develop a system for diagnostics of a diesel engine. In the article are presented curves, which describe the characteristics of the crankshaft angular velocity variation in transient state, and the fluctuations of the rotation at idle speed which are described as parameters for diagnosing these types of engines. The obtained results indicate that this method can find practical application in the diagnosis of diesel engines. This will allow the implementation of perspective methods for diagnostics of these types of engines, for which modern diagnostic tools are inapplicable due to their design features.
KEYWORDS: Diagnosis, angle velocity, acceleration, diagnostic system

INTRODUCTION

The diagnostic systems can be described as the sum of diagnostic tools, diagnosed object and contractor (operator).

The main stages in the development of diagnostics systems are:

- choice of object for diagnosis;
- definition of diagnostic parameters which will be measured;
- development and testing the system used for measuring the diagnostic parameters;
- data processing and analysis of measured parameters;
- defining the normative values of diagnostic parameters;
- development of algorithms for diagnostics.

The diagnostic systems can be divided into two groups:

- systems for control of the performance and the reliability of the technical processes;
- systems for definite detection of faults based on type, size and location.

PRINCIPLE OF OPERATION OF THE SYSTEM

Since the system is developed to control the performance and the reliability, as well as to locate the faults in the diagnosed object, it is required that this system is to measure the value of the current angular velocity, angular acceleration and cyclic crankshaft speed fluctuation of diesel engines. The system is designed for diagnostics of diesel engines used in road construction and agricultural machinery.

The calculation of the current angular velocity and the angular acceleration is based on signals received from the inductive transducer mounted against the flywheel ring gear. To determine the current value of the angular velocity and the angular acceleration the duration of the impulses generated by the transition of two successive flywheel teeth along the sensor are measured. Obtained in this way, the impulse of unknown duration t_x, is filled with signals of known constant frequency with period T_e, received from clock generator. The impulse duration of the measurements is determined with the following the mathematical relation:

$$M = t_x \,/\, T_e$$

where: t_x - impulse with unknown duration, Te - constant frequency

At maximum engine speed 3000min^{-1}, the frequency is:

$$F_{max} = 3000/60 = 50 \text{ Hz};$$
$$T = 20\text{ms}$$

For flywheel is with 144 teeth

$$t_{xmin} = 20\text{ms}/144 = 138\mu s$$

At minimum engine speed 300 min^{-1}

$$F_{min} = 300/60 = 5 \text{ Hz};$$
$$T = 200\text{ms}$$
$$t_{xmax} = 200\text{ms}/144 = 1380\mu s.$$

The precision required is taken into account when determining the cyclical fluctuation of the crankshaft speed. The clock generator's frequency is determined according to the calculations given in Table 1. It is estimated that using a clock generator with a frequency of 8MHz gives the required accuracy for the conducted measurements. The memory capacity used for intermediate data storage was also subject of consideration when designing the system.

Table 1. The clock generator's frequency

$F_{ген}$	T_e	n_{max} = 3000 min^{-1}	n_{min}=300 min^{-1}
1MHz	1 μs	138	1380
2MHz	0.5 μs	276	2760
4MHz	0.250 μs	552	5520
8MHz	0.125 μs	1104	11040
10MHz	0.1μs	1380	13800

The system is based on single-chip microcontroller ATMEL – AT89C51. It consists of the following components: microcontroller ATMEL – AT89C51, 32kB external memory RAM62256, 16 bit programmable timer PIT8254, 7474 D-type flip-flop, clock frequency generator - 8MHz, RS232 driver/receiver MAX232, Programmable Peripheral Interface - PPI8255, control panel, display unit and primary transducer (Fig.1).

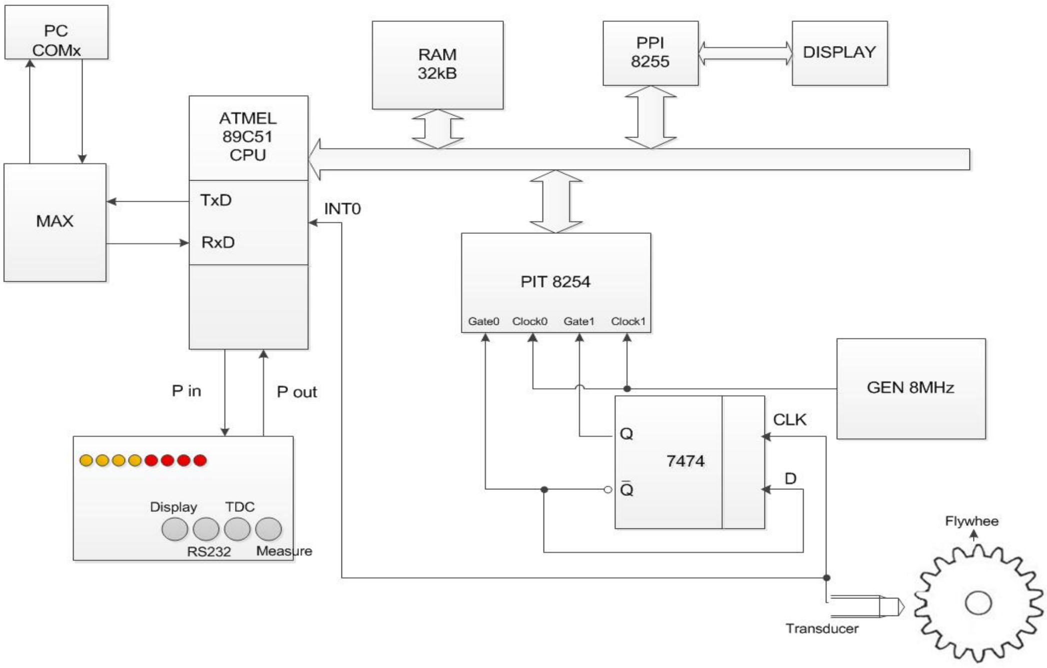

Figure 1. Block scheme of the device

The signal frequency received from the transducer is a function of the speed. The length of each impulse is uneven due to the fluctuation of the crankshaft speed.

The measurement unit is the programmable interval timer PIT 8254, which perform timing and counting functions. The two channels of clock inputs Clock0 and Clock1 of Timer0 and Timer1, work successively over time. N^{th} Impulse t_x generated by N^{th} tooth is measured by Timer0, and N+1 tooth by Timer1. Each Impulse t_x obtained from the sensor allows trough Gate0 or Gate1 the counting of the Timer0 or Timer1.

D-flip-flop 7474 is set in counter mode. The inverted output $\overline{Q}$ is connected directly back to the Data input giving the device "feedback". It works as a binary divider for frequency division and shifts the timers input channels. N^{th} impulse triggers Q and N+1 pulse triggers $\overline{Q}$. This triggers the countdown through Gate0 and Gate1. It allows entry of the reference pulses with period T_e from the clock generator respectively to Timer0 and Timer1.

Available for reading during the measurement of N^{th} impulse in Timer1 is N-1 pulse (past event), respectively when measuring pulse N+1, Timer0 reads N^{th} pulse.

At the end of each period of the input impulse an interruption INT0 is activated. This interruption serves for reading the completed period from Timer0 and Timer1. A program redirects the signal reading from Timer0 to Timer1. The resulting number, dimensionless value M, is stored in sequential order in the external memory. The RAM capacity of 32kB allows 16 384 records.

The parallel interface PPI8255 is a general-purpose I/O interface used to connect the eight digits, seven segment digital external display unit to the system bus. By pressing the "display" button *the data stored in the memory system is displayed successively from 0 to 16,383th measurement. The function of this peripheral equipment is to help verifying the system's proper work. Redundant clock generator with referenced frequency, which simulate signal from the sensor, is used to control the operation of the measuring system.*

When the "measurement" button is pressed, the system goes into a standby. The actual recording begins when the system receive the signal which simulates the TDC position of the crankshaft. When the measurement is initiated, a yellow LED indicator lights up. When the system memory is full, the LEDs are deactivated, which show that the process of data recording is completed. During the measurement, the process cannot be interrupted (except by hardware Reset of the CPU). The recorded data can be latter transferred to a PC through COM port.

EXPERIMENTAL RESULTS

The parameter that describe most precisely the diesel engine overall technical condition is the change in the angular acceleration of the crankshaft during transient state (from idle to maximum engine speed). Figure 2 shows the engine D240 curve characteristics of the angular velocity change obtained using the date from the developed device.

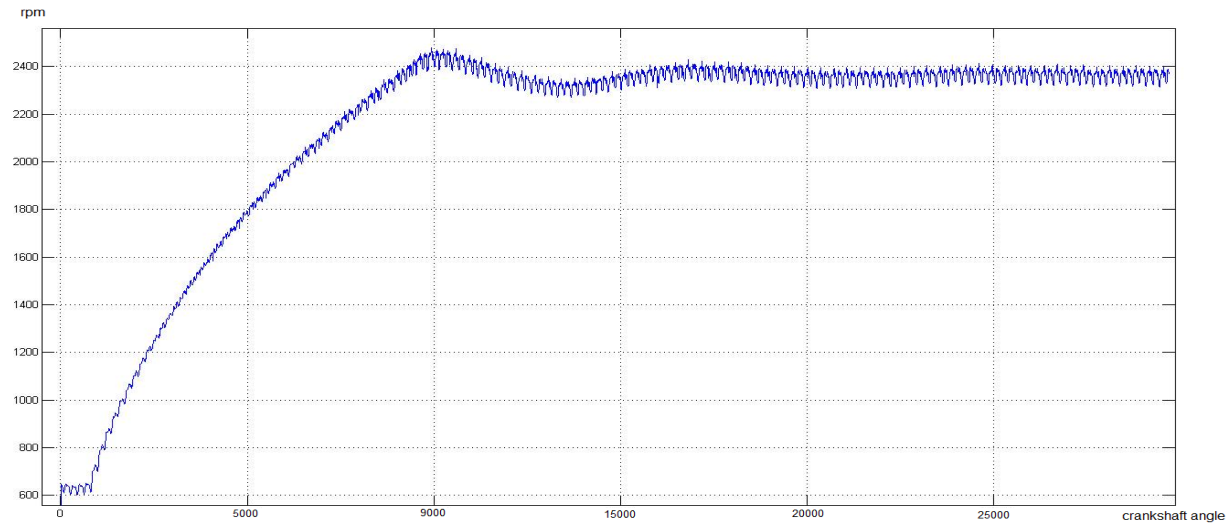

Figure 2. Curve of crankshaft angular velocity characteristic in transient state

Another main parameter used to determine the technical condition of the diesel engine is the internal-cyclical fluctuation (irregular rotation of the crankshaft for one cycle of the engine) at idle speed. Faults and malfunctions of individual engine cylinders alter the internal cyclical rotation which leads to fluctuations. The type of a malfunction or failure can be determined by the curve resulted from the experiments. In order to smooth out the crankshaft fluctuations, the experimental curve is processed with a moving average filter.

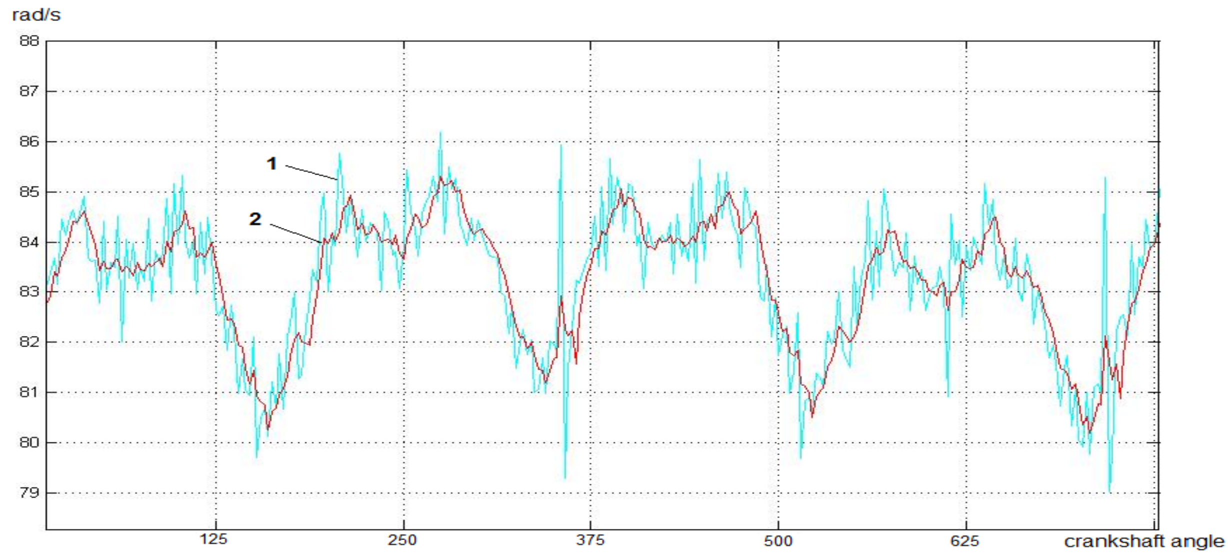

Figure 3. Visualization of the experimental curve (1) after the first (2) smoothing with moving average filter

Figure 3 presents the experimental curve (1) and curve (2) resulted after first smoothing by moving average filter. For more accurate analysis on the curve is applied second smoothing, presented in Figure 4.

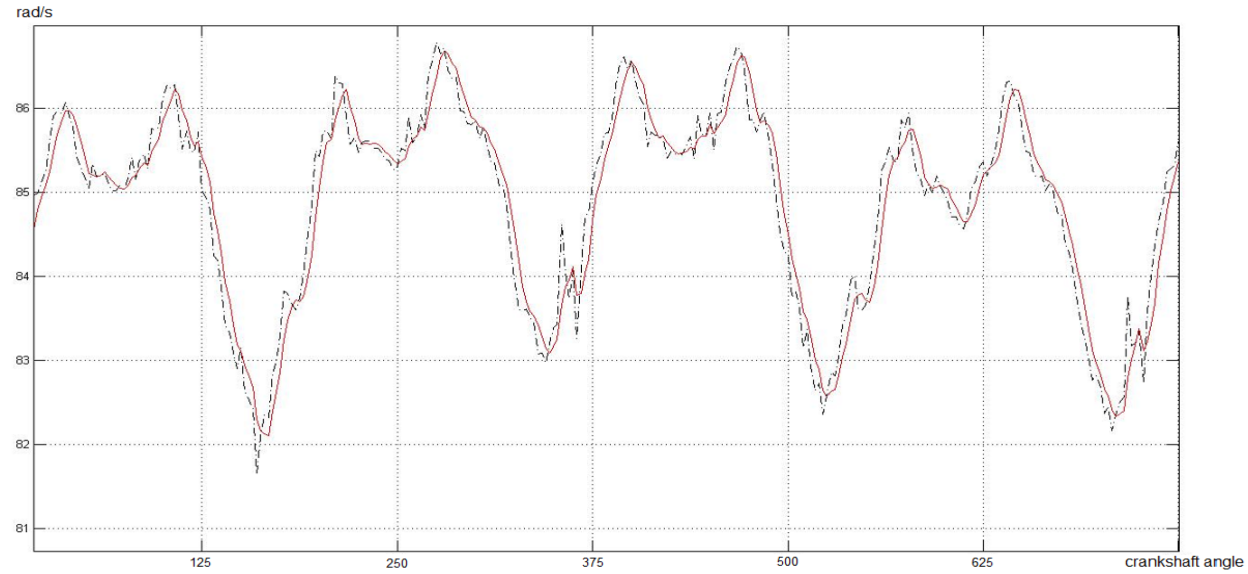

Figure 4. Visualization of the experimental curve after the first (1) and second (2) smoothing with moving average filter

CONCLUSIONS

The obtained results indicate that this method can find practical application in the diagnosis of diesel engines. This will allow the implementation of perspective methods for diagnostics of these types of engines, for which modern diagnostic tools are inapplicable due to their design features.

For this purpose, it is necessary to carry out further studies in order to determine the invariance, sensitivity and normative values of diagnostic parameters which will be used.

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