TUNING METHOD FOR HIGH-SPEED MARINE DIESEL ENGINE MB820 TYPE

Tomasz Lus

Polish Naval Academy, Mechanical-Electrical Faculty
Śmidowicza Street 69, 81-103 Gdynia, Poland
tel.: +48 58 6262629, fax: +48 58 6262648
e-mail: t.lus@amw.gdynia.pl

Abstract

Checking and tuning of the fuel injection valves opening pressures, fuel valves timing and exhaust or inlet valves clearances is a common practice in high-speed marine diesel engines maintenance. Cost lowering tendency in engine maintenance schedules and unmanned vessel's propulsion plants need new approach to these old and reliable procedures. Conventional maintenance methods for engine valve gear mechanism depend on valve clearances checks between valve stem and rocker arm and valve timing diagram checks on crankshaft flywheel. But how to observe valves' timing diagram on working engine and what is the difference between static and dynamic valves timing diagram and in the end how engine load and speed changes disturb observed parameters? Answers for these and other questions for high-speed marine diesel engines MB820 type are given in this paper. Dynamic valve gear timing diagrams are indispensable to perform an accurate engine tuning. A new original diagnostic and tuning method for high-speed marine diesel engine MB820 is presented in the paper. In the principle this method based on measurements of: internal cylinder pressure curves and on vibration signals. Typical diagnostic methods which based on vibration signals analysis are sensitive to engine load and speed changes. Researches presented in this paper were focused on the possibilities and differences of the dynamic timing diagram assessing at engine rated load and when idling.

Keywords: *marine diesel engine, diagnostics, tuning, fuel injector, valve gear*

1. Introduction

One of the biggest marine diesel engine manufacturers, the Wärtsilä firm, in its new technical management concepts [1] cuts costs for ship owners by online monitoring and dynamic maintenance planning. To prepare Dynamic Maintenance Plan marine diesel engines have to be equipped with condition monitoring system which is standard for Wärtsilä latest design engines. Trying to adopt similar maintenance systems on to the older generation of marine diesel engines the appropriate monitoring tools have to be prepared to assess on-line and in the real time the technical condition of the engine.

Trying to solve this problem the new diagnostic method was tested on compact high-speed marine diesel engines type MB820. Typical diagnostic methods which base on the analysis of vibration signals amplitude or their frequency are sensitive to engine load and speed changes [2]. The new diagnostic method is based on the envelope of vibration acceleration signal analysis in crank angle domain during engine operation whereas the conventional maintenance methods for valve gear mechanism of the engine depend on valve clearances checks between valve stem and rocker arm and valve timing diagram checks on crankshaft flywheel. So-called "dynamic" valve gear timing diagrams are indispensable to perform an accurate engine check and tuning. There are several questions to be answered: how to check valves' clearances without stopping the engine and dismantling it, how to monitor valve gear timing diagram on running engine and what the difference exists actually between "static" and "dynamic" valve gear timing diagram. Answers to mentioned questions for submarine diesel engines type MB820 are given in this paper. Polish Navy operates four KOBBEN type submarine vessels. Diesel generators on these ships consist of MB820 type diesel engines.

2. Basic parameters of the MB820 type marine diesel engine

The MB820 is a high-speed four-stroke diesel engine of compact design [4], which operation is based on the pre-chamber combustion process. The end of the engine from which the power is taken off (flywheel end) is designated as the rear. The term “anticlockwise” or “clockwise” and the numbering of the cylinders as well as the direction of rotation of the crankshaft are as seen from rear. The engine has 12 cylinders those are arranged in two banks inclined at an angle of 60^o to one another. The first and the seventh cylinder are located at the rear therefore, and the direction of the crankshaft’s rotation is anticlockwise (Fig. 9-11). Each cylinder has one fuel injector. Injectors are boosted by two injection pumps fitted on the gear case one for each bank of cylinders. The left pump carries the speed governor. General technical data of the MB820 type engine and its “static” tuning parameters are given in Tab. 1 and 2. Each cylinder has 2 inlet and 2 exhaust valves, the operation of which is controlled by a camshaft common to both cylinder banks, by means of tappets, push-rods and rocker arms.

Tab. 1. MB 820 type diesel engine general technical data

1	Working cycle	Four stroke, not turbocharged
2	No. of cylinders	12 in “V”
3	Cylinder bore/Piston stroke	175 mm/205 mm
4	Total displacement volume	59.2 litres
5	Injection system	Diesel pre-chamber
6	Compression ratio	18.5 : 1
7	Full load max. speed/ Idling speed	1400 rpm / 600 rpm
8	Continuous output at 1400 rpm	600 HP
9	Firing order	1-8-5-10-3-7-6-11-2-9-4-12
10	Inlet/Exhaust valve clearance when cold	0.40 / 0.45 mm
11	Injection nozzle opening pressure	170-175 kg/cm^2
12	Dry weight	3710 kg

Tab. 2. “Static” tuning parameters of the MB820 type diesel engine

1	Inlet valve opens	14°	before TDC
2	Inlet valves closes	56°	after BDC
3	Exhaust valve opens	48°	before BDC
4	Exhaust valve closes	19°	after TDC
5	Valves overlap	33°	14° + 19°
6	Start of fuel feed-in when idling	24°	before TDC
7	Adjustment range of automatic injection timer	24°-36°	before TDC

3. The MB 820 type marine diesel engine preparation to the tests

The main goal of the tests presented in this paper were to check if there is a possibility to assess engine “dynamic” tuning parameters in the whole range of engine speed and load and what are the differences between “dynamic” timing diagram at full engine load and when idling. Vibration signals were measured using typical vibration sensor (Fig. 1) on the intake manifold connected to the cylinder heads of separate bank in the same point one by one at the same engine speed and load. As a reference signal for the vibration signals processing cylinder pressure signal was used. The MB820 type engine analogically to the most of the high-speed marine diesel engines (similarly to the land traction engines) is not equipped with cylinder indicator valves. In order to measure the internal cylinder pressure on MB820 engine (which is not equipped with indication cocks) the decompression channels were used. KISTLER pressure sensor type 7613B was connected in place of the decompression valve as it is shown on the Fig. 1.

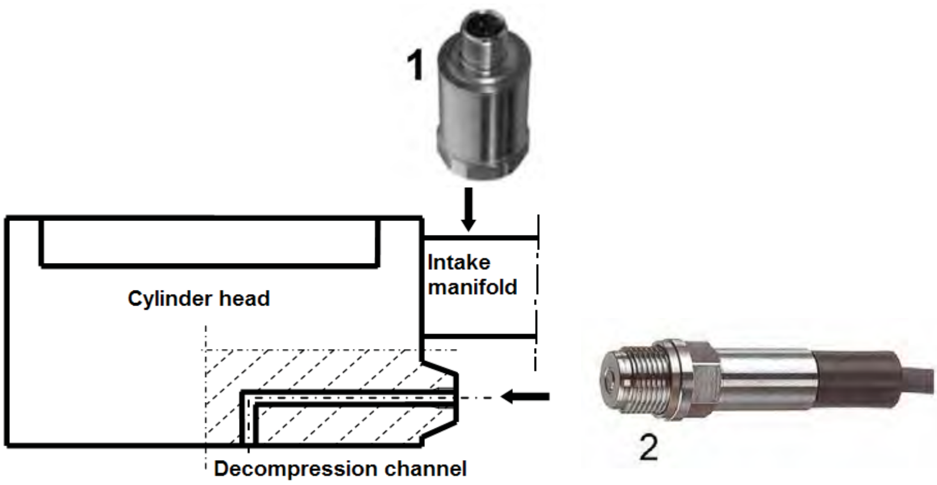

Fig. 1. Cylinder head with the vibration (1) and cylinder pressure (2) sensors passed through the decompression channel

This solution could have been performed on the two cylinders of the 12-cylinders V-shaped engine only (on the cylinder number one in the left bank and on the cylinder number 7th in the right bank) because of a very difficult access. The cylinder pressure sensor should not be used on the engine permanently because it could endanger the engine, especially during the start. Traces obtained during investigations of the cylinder pressure are shown in the Fig. 2. Exact part from the registered pressure traces obtained during the tests are used as a reference (trigger) signal to synchronizing vibration signals from all of the six cylinders in one of the banks of cylinders.

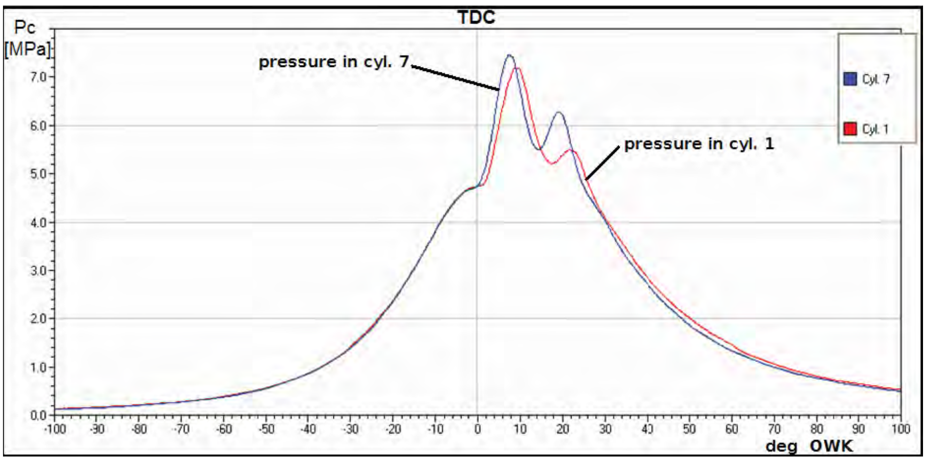

Fig. 2. Cylinder pressure curves in cylinders No. 1 and No. 7 measured under rated load (amperage 1800A) of diesel generator and speed of n = 1354 rpm

4. Test results and discussion

The typical visual analysis of the vibration signal in the time/angle domain gives usually limited information. The original method presented in this paper precisely is the angle analysis of the envelope of vibration acceleration. That method for low-, medium-, and high-speed marine diesel engines was worked out in the Technical Institute of Ship Maintenance of the Polish Naval Academy in Gdynia and is still evaluated for new and more complex marine diesel engines.

The signal is analyzed only as an event in time/angle domain and when the sampling frequency is high enough as well as the time/angle axis is stable, having appropriate reference signals one could easily check the signal sequence order (signal pattern). The proper vibration signals sequence order (proper signal pattern) means that the engine is in a good technical condition. A problem appears when one has to observe vibration signals on multi-cylinder engines. Vibration signals registered simultaneously on cylinder heads of one of the two banks of 12 cylinders MB820 diesel engine are shown on the Fig. 3. Cylinder pressure signal from the cylinder No. 1 is presented together with vibration traces. There is not easy to recognize and assign to the separate signals exact events in the engine fuelling or valve gear systems. On the Fig. 4 the vibration signal traces from six cylinder heads at engine rated power were moved up by 0.2 Volt but it is still not easy to recognize the characteristic timing points of the working engine.

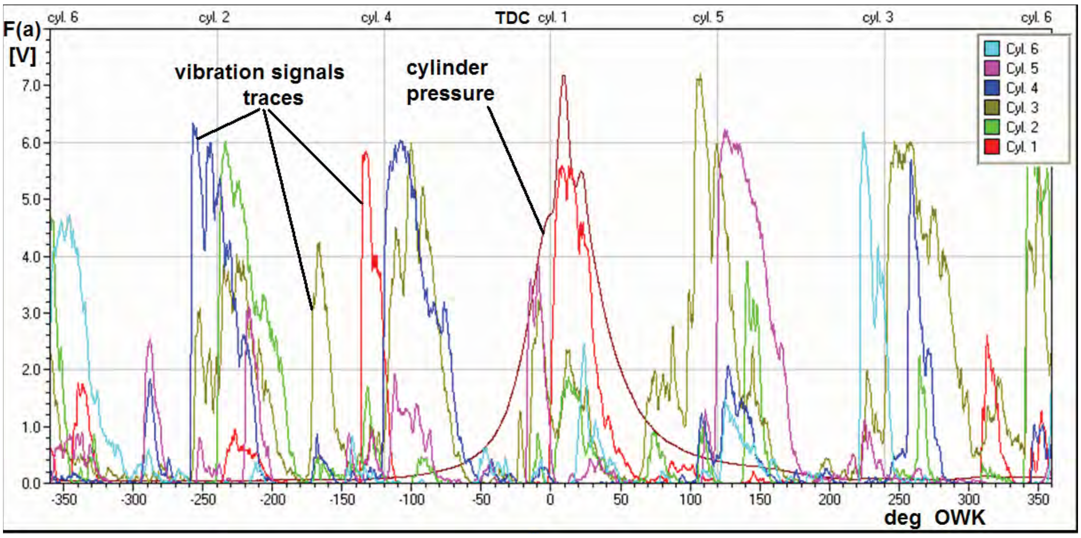

Fig. 3. Cylinder pressure signal from the cylinder No. 1 as a reference signal for vibrations traces from six cylinder heads in the same bank of high-speed marine diesel engine

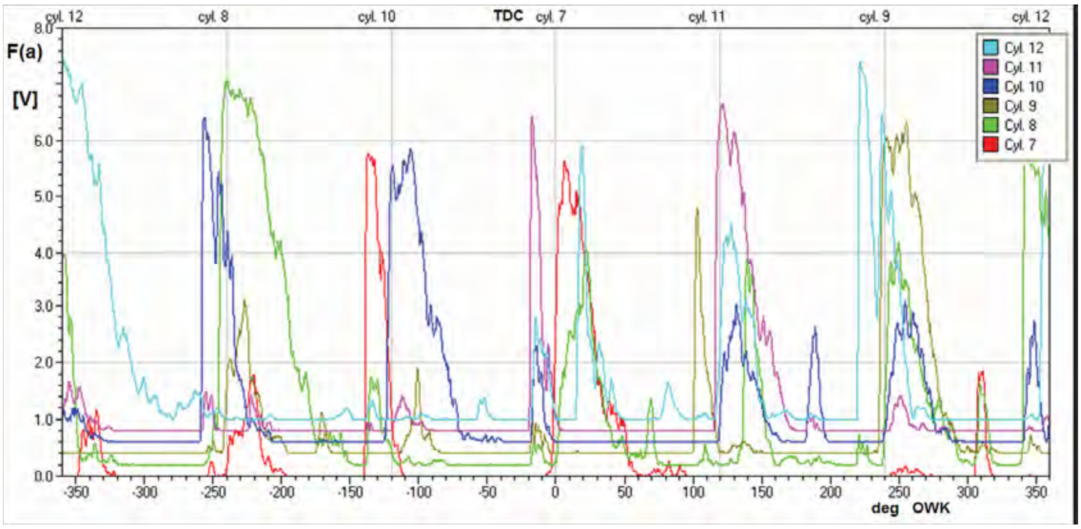

Fig. 4. Vibrations traces from six cylinder heads in the same bank of high-speed marine diesel engine moved up by 0.2 Volt – engine at rated load

In the next step the vibration signal traces from six cylinders were shifted to the TDC (Fig. 5) of the first (in this bank) cylinder to assure higher accuracy of analysis. Additionally, on the Fig. 5 the static engine timing points are shown: ZZw – means static exhaust valves closes, ZZd – means static inlet valves closes, PW – means static point of start of fuel feed-in when idling, OZw – means static exhaust valves opens and OZd – means static inlet valves opens.

The places where signals from different (adjacent) cylinders could interfere (for 4-stroke 6 cylinder diesel engine it is usually ±120°, ±240° to TDC) are shown on the Fig. 6. The strongest signals from adjacent cylinders could make some limitations in the tuning process.

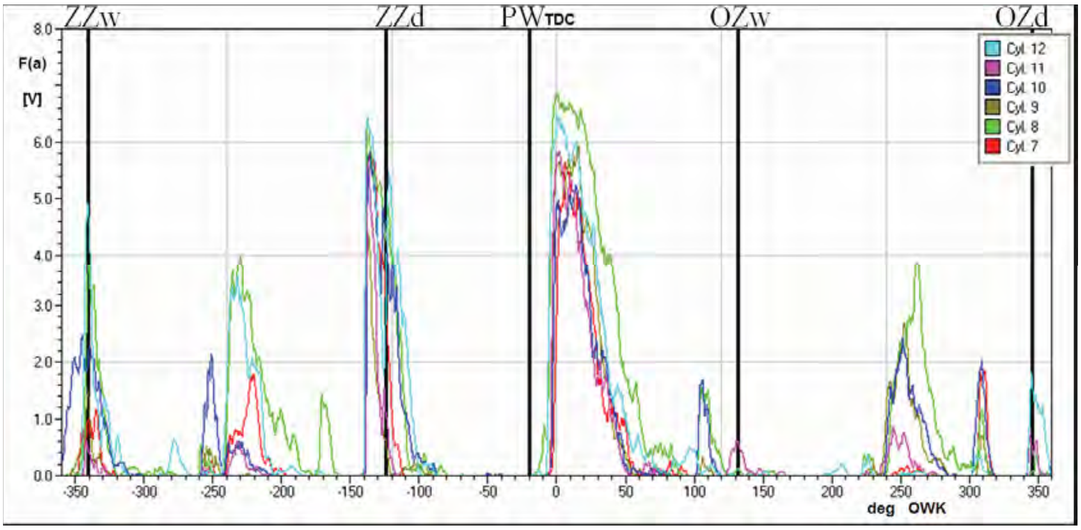

Fig. 5. Vibrations traces from six cylinder heads in the same bank of high-speed marine diesel engine shifted to the TDC of the first cylinder of their bank – engine at rated load

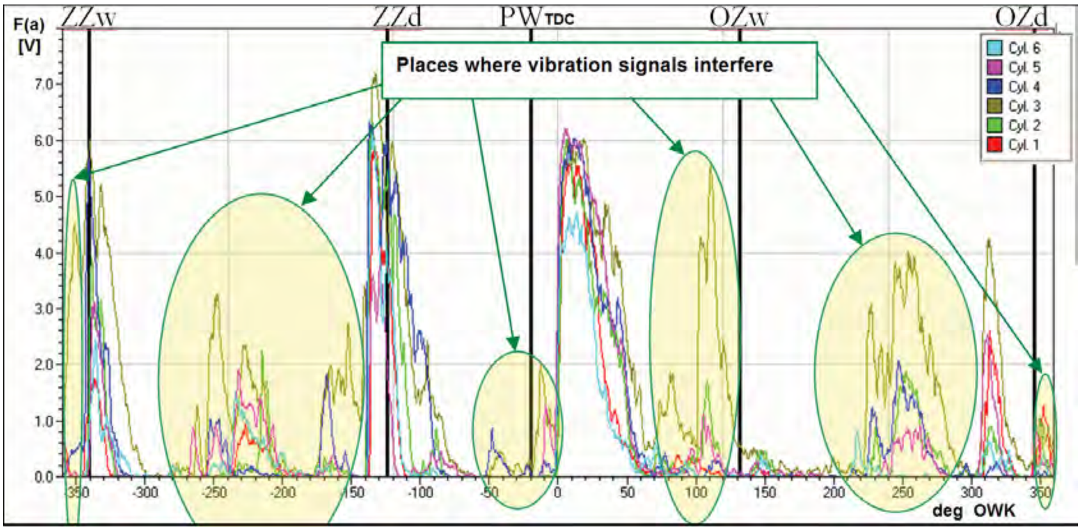

Fig. 6. Specific places where vibration signals from different cylinders interfere with one another

The same signal processing was used to the vibration traces taken from the engine cylinder heads when idling (Fig. 7 and 8). In such engine conditions, analogically to the rated load, moving vibration traces up do not give expected results (Fig. 7). There are too many places where signals from different cylinders coincide and interfere with one another. In case when vibration signals are shifted to the TDC (Fig. 8) of the first cylinder in the bank the traces pattern gives the analyzer operator possibility to recognise characteristic engine timing diagram points even if engine idling.

Using special analyzing system with “zoom” function (as it is shown on Fig. 9-11) each part of the diagram could be magnified to read-out the engine dynamic timing parameters. Using a cursor the analyzer operator can assess angles of fuel injection valves openings and valve gear timing for each cylinder in the same bank with reasonable accuracy.

Chosen results from the MB820 engine type investigations are shown on Fig. 9-11. At the left sides of these figures magnified (using “zoom” function) parts of vibration signals at the characteristic timing diagram points are presented. At the right sides “dynamic” (empty white dot) and “static” (fill black dot) engine timing diagrams are presented. The differences between angles in “static” and “dynamic” conditions are also presented. The measured differences between mean values of angles for left bank (1-6 cyl.) and right bank (7-12 cyl.) in the “dynamic” diagram for engine rated load and idling are presented in the Tab. 3.

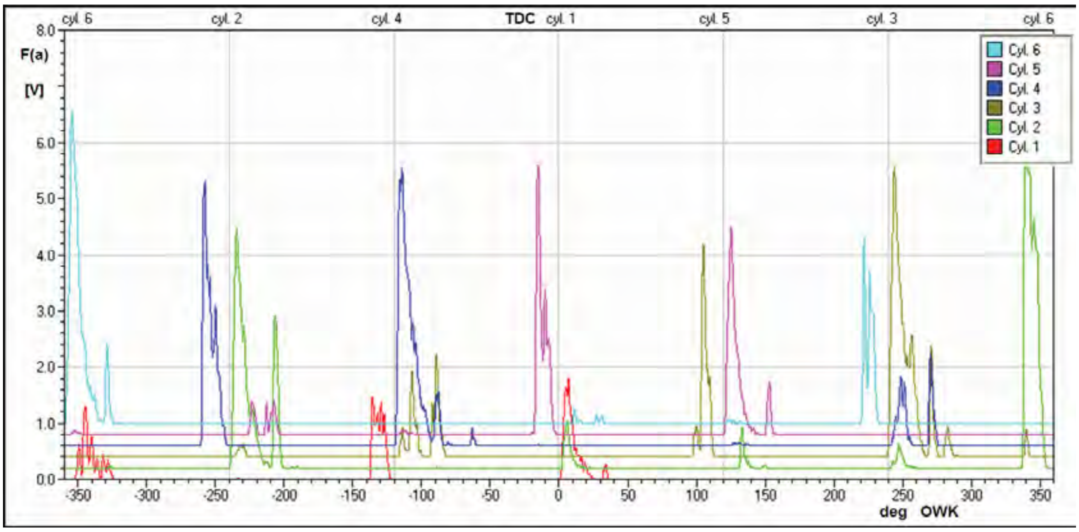

Fig. 7. Vibrations traces from six cylinder heads in the same bank of high-speed marine diesel engine moved up by 0.2 Volt – engine idling

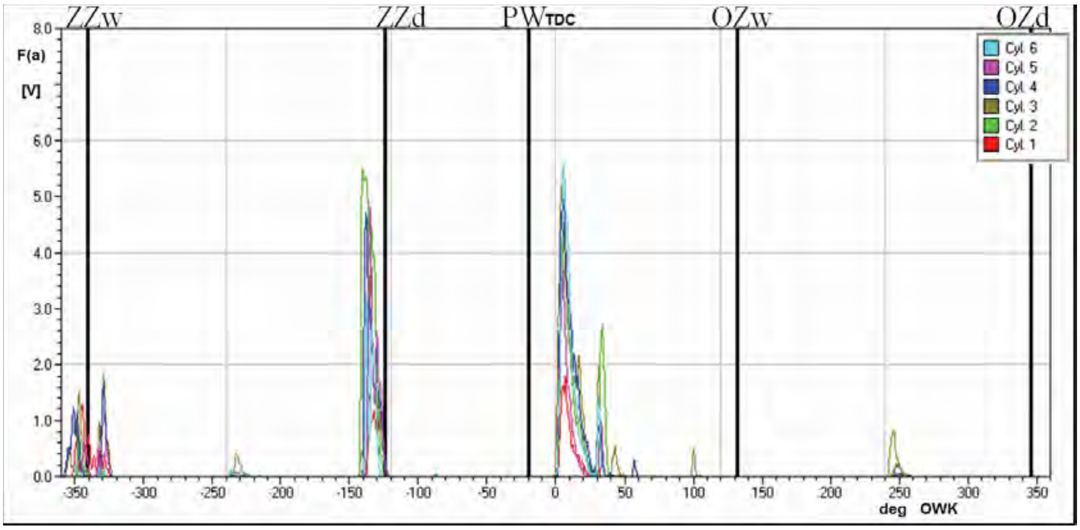

Fig. 8. Cylinder vibrations traces from six cylinders in the same bank of high speed marine diesel engine shifted to the TDC of first cylinder of their bank– engine idling

Tab. 3. Mean values of the „dynamic“ diagram timing parameters for the left bank (1-6 cylinders) and for the right bank (7-12 cylinders) at engine rated load and when idling

Mean value/bank	Engine rated load				Engine idling		
	ZZw [°]	ZZd [°]	Pw [°]	OZd [°]	ZZw [°]	ZZd [°]	Pw [°]
mean 1-6	-343.5	-138.5	-1.5	308.2	-349.6	-139.0	0.6
mean 7-12	-344.9	-139.7	-5.0	304.1	-345.9	-133.8	-0.7

Conclusions

Diesel engines technical condition assessment is a very complex process. Most of the malfunctions and troubleshooting in the diesel engine installations are generated by the fuel injection system and valve gear mechanism. According to the engine manuals crews should inspect these systems in relatively short periods. Opening and closing of the fuel injection valves, inlet and exhaust valves generate vibration signals in engine structure. There are some tools available in vibration signal analysis which gives the opportunity to trace changes in signal patterns in real time monitoring systems. Presented special vibration method gives opportunity to change the engine maintenance

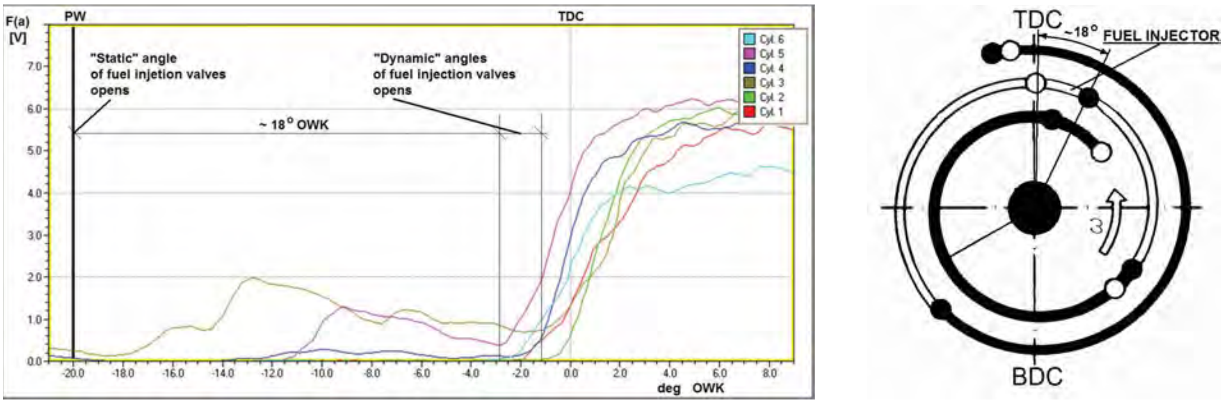

Fig. 9. Dynamic and static angles of fuel injection valves open of MB820 type diesel engine

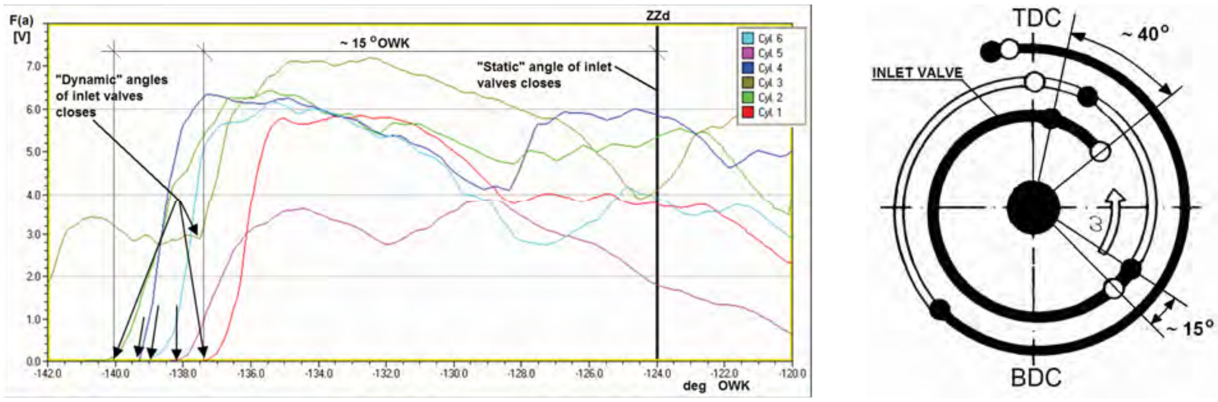

Fig. 10. Dynamic and static angles of inlet valves gear timing diagrams of MB820 type diesel engine

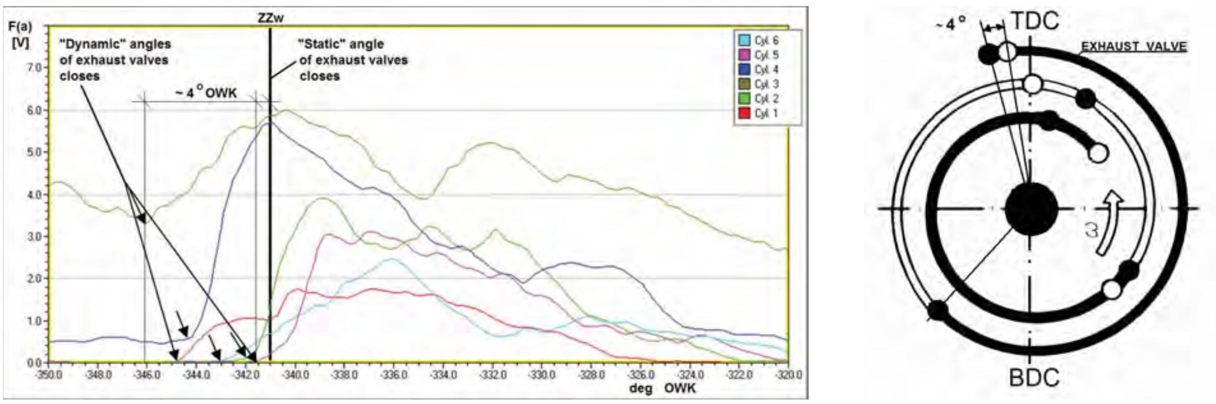

Fig. 11. Dynamic and static angles of exhaust valve gear timing diagrams of MB820 type diesel engine

philosophy from scheduled to condition based maintenance without fear about real operating engine conditions. The "dynamic" valve gear mechanism timing diagram could be observed when using a proper method of signal processing. Dynamically estimated values of angles of valves closings and openings are different to the values given in the engine manual. These angles are usually determined in static conditions because of what a special database for prophylactic engine controls has to be created. Dynamically measured the fuel injection valve opens and closing angles and exhaust and inlet valves opens and closing angles are determined by the engine speed and load. Taking into account that maintenance may be taken in different load conditions the database should contain the whole spectrum (whole map) of measured parameters.

Not every engine timing diagram characteristic point had been observed and measured using presented method. It was not possible to separate with acceptable accuracy the signals coming from exhaust valves opens (Fig. 11 – right) because the sensor was located at the external parts of the cylinder heads whereas the exhaust valves are located close to the middle to the engine crankcase. Additionally signals from the fuel injector's closings were not observed because of vanishing during long expose time of signals generated by its openings. To improve the next tests engine should be prepared to screw-montage of the vibration sensor directly to the cylinder heads or intake manifold (magnetic sensor montage restricted the measured frequency band to about 1-3 kHz). The vibration sensors should have higher resonance frequency. The high-pass frequency filter should have been changed and envelope filter should have lower time constant.

References

[1] Klockars, T., Eykerman, A., Mayr, I., *Making the most of perfect maintenance timing*, indetail, Wärtsilä Technical Journal, pp. 57-60, Finland 2010.

[2] Madej, H., *Mechanical malfunction diagnostics in combustion engines masked Bay electronic governing device*, Institute Maintenance Technology Scientific Publisher – PIB, Radom 2009.

[3] Wimmer, A., Glaser, J., *Engine Indication*, Institute of Technique Application Publisher, Warsaw 2004.

[4] Marine diesel engine MB 820N/1type manual, Mercedes-Benz.