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IMPACT OF RISE OF EXHAUST RESISTANCE AT TORQUE AND ANGULAR SPEED OF TWO-STROKE ENGINE

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Abstract

It is assumed that elements of Exhaust Gases Cleaning Systems creates additional resistance along fumes duct and can affect energetic process of combustion. In the paper are presented results of researches aimed on detection and recognition of dumping effect in the exhaust pipeline using devices dedicated for engine's torque and angular speed measurement. The experiment was carried out in test stand of Gdynia Maritime University; equipped with one-cylinder, low speed engine working in two-stroke mode. Effect of increasing of gas flow resistance was achieved by installation of shutters in cross-section of exhaust pipe. The shutters diminished active flow „window" for 50% of normal crossection area of the exhaust pipe The plan of measurements encompasses registration of Instantaneous Angular Speed of the engine's shaft and parallel registration of Instantaneous Value of Shaft Torsion, what reflect fluctuation of torque. Value of angular speed and toque enables exact calculation of power produced by the engine. Experiment included measurements at different levels of engine's load and with changes of mean rotational speed. Angular speed and shaft's torsion were measured and recorded using system ETNP-10 which is based on optical sensor and set of toothed discs. That method gives high accuracy of angular speed and torsion measurement. Results of experiment are presented as difference of related curves of values' variations of angular speed and torsion occurring at the propulsion shaft connecting the engine and the water brake.

Keywords: *diagnostics, diesel engine, exhaust pipe resistance, torque and angular speed*

1. Introduction

In two stroke CI (compression – ignition) engines, charging of fresh air and forcing out remaining combustion gases occurs during one stroke. That mode of operation requires blowers or turbo-chargers for proper cleaning and filling fresh air load (scavenging). Scavenging process is strictly related to fresh air and exhaust gases flow condition through in cylinder space and through valves and gas piping [7]. It means that all kind of malfunction of exhaust valve's timing and changes of geometry of outlet channels and pipes can disturb proper exchange of fresh air load [1]. Improper exhaust valve timing is in mostly cases caused by mechanical reasons and is quite easy to adjust. Changes of piping geometry can caused by natural process of combustion products collection in vulnerable places like flanges or piping knees or by installation of additional devices what increase flow resistance of pipe duct.

Requirement for neutralisation or elimination of environmentally dangerous contains of combustion exhaust gases is one of the most important tasks, which contemporary engineers encounter during propulsion design. The problem is very serious and not easy solutions can be taken. All installations dedicated for NOx, SOx and soot reduction make exhaust system more complicated, requires space and of course must be considered as source of additional resistance of exhaust gases flow [6, 7].

The aim of researches presented in this paper was very firs analysis of potential impact of gas flow dumping in exhaust channel at two stroke engine parameters, and recognition of possibility of monitoring of parameters' changes, by measurement of engine's angular speed and torque fluctuations. All measurements were conducted at one cylinder, two-stroke CI engine, in Gdynia Maritime Academy laboratory stand.

2. The characteristics of the engine and test rig

Testing measurements were carried out at the test bed in Gdynia Maritime University Engines Laboratory. The engine, presented in Fig. 1 is laboratory unit with possibility to change working mode from four-stroke cycle to two stroke one. Scavenging process is executed by blower powered by electric engine, with possibility to regulate intensity of intake air flow. Engine load is executed using water brake, which torque is set up using weights mounted at brake arm. Level of torque can be also controlled at torque meter ETNP-10 control panel. Rotational speed of the engine is in range of 200 to 600 revolutions per minute. In practice, in order to keep parameters as close as possible to ships engines working parameters, the values between 200 and 270 rev/min are adjusted. Maximum engine power in two-stroke mode is 73 kW at 600 rev/min. L-22 engine can burn standard diesel fuel or heavy fuel oil, and test stand is equipped with two fuel systems.

Fig. 1. Test stand with engine L-22 and water brake

Angular speed and torque values were measured and recorded with using ETNP-10 system, which was designed for on-line torque and revolutionary speed control. That system is based on optical sensor counting number of impulses going through toothed discs and recognizing “length’ of tooth or slot. Length of teeth gives information about angular speed and average value of one revolution gives revolutionary speed of engine’s shaft. Mounting of two independent discs with proper distance between them gives information about shaft’s torsional twist, what is measure of current level of torque. This way, from one emitter, two information at the same time can be obtained [3, 4].

System ETNP allows to register 10 subsequent revolutions and every revolution consist of 60 angular speed signals and 30 torque variation signals. It is because of construction of the discs, with 30 teeth each. Construction of toothed discs is presented in Fig. 2.

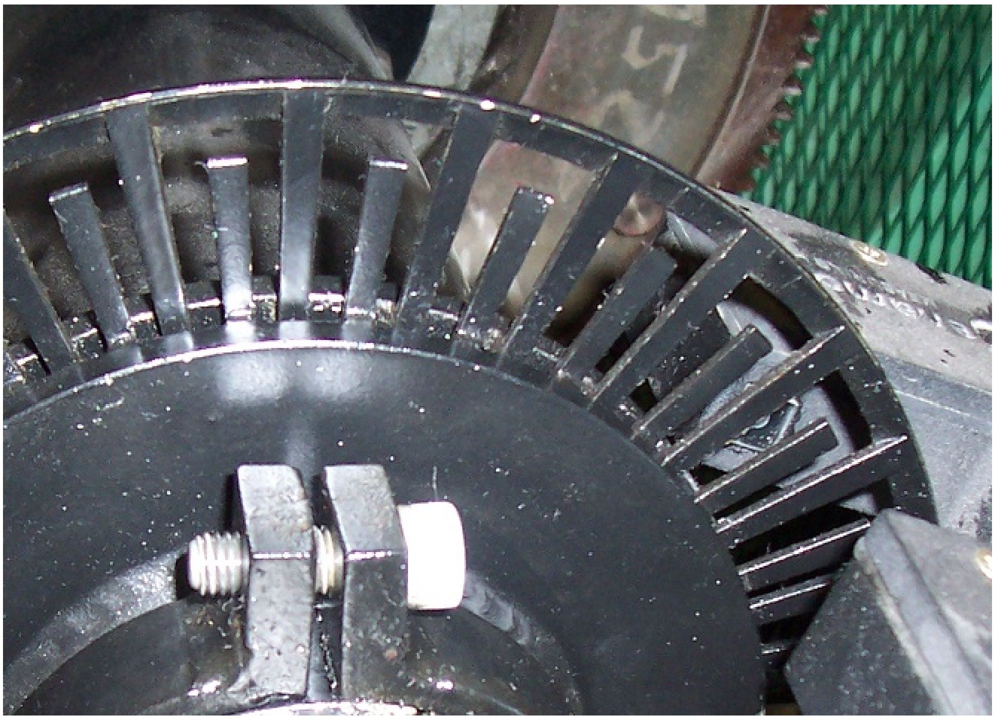

Fig. 2. Toothed discs for measurement of torque and angular speed

3. Plan of experiment

In order to get clear picture of engine's behaviour when exhaust gas duct's resistance was increased, the plan of experiment included measurements at four levels of engine's power, what was carried out by different sets of torque and angular speed. Assumed levels of torque were respectively 20%, 40%, 50% and 70% of nominal value what gives 234 Nm, 468 Nm, 585 Nm and 702 Nm. Torque values were corresponding with speed of 220 rev/min, 240 rev/min and 270 rev/min. First series of measurements were carried out without diaphragm in exhaust system and subsequently sets of pairs load-rotational speed were repeated with diaphragm, which diminished area of cross section of the smoke pipe by 50%. Analysis of results relayed at comparison of deviations of runs of torque with and without diaphragm and angular speed with and without diaphragm [2].

Ambient condition have some impact at engine output parameters, thus must be considered during creating of diagnosis. When level of recorded disturbances taken, as diagnostic signal is comparable with the level of changes due to atmospheric condition changes, implemented method is worthless. To exclude such case, series of independent measurements under different outer conditions, without diaphragm, were done. Analysis of obtained results enabled determination of level of deviations caused by non-repeatable outer conditions [5].

4. Results of experiment

In Fig. 3a. and 3b. are presented comparisons of runs of relative value of angular speed. Relative value is calculated as quotient of instantaneous value and mean value of three subsequent revolutions. Measurements were done at two revolutionary speeds, 220 and 270 rev/min, and under load of 20% of nominal. At the picture, one can observe very close runs of both speeds. Maximum difference between peak values was around 0.8%, in both runs. Average speed difference between mean values for setup 220 rev/min was 1.7% and for 270 rev/min was 0.08%. It means that reference value based at measurement of parameters without diaphragm has to be determined in the same ambient condition, to avoid errors.

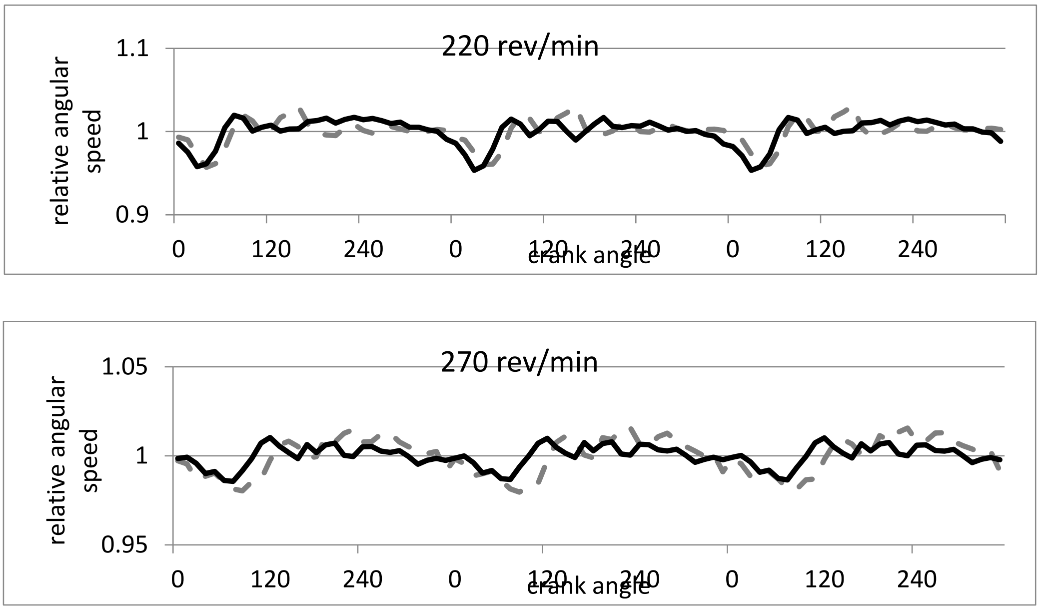

Fig. 3. Comparison of instantaneous angular speed runs recorded in different outer conditions

In Fig. 4 are presented results of comparison of curves of relative Instantaneous Angular Speed (IAS) runs with and without diaphragm in exhaust system. As can be observed, that oscillations around mean value of three subsequent revolutions in the case when engine load is low (20% of nominal) and adjusted rotational speed is 220 rev/min. shows shift in phase (Fig. 4). When speed was increased to 270 rev/min, phase shift almost fully disappeared (Fig. 6 and 8). There are not differences between runs when load was higher than 50% of nominal (Fig. 5 and 7). It let us come to the conclusion that resistance due to diminishing of pipe crossection by 50% does not affect angular speed of the engine working at normal load level. Only low level of load (for example – engine is warming up) is characterised by IAS irregularity.

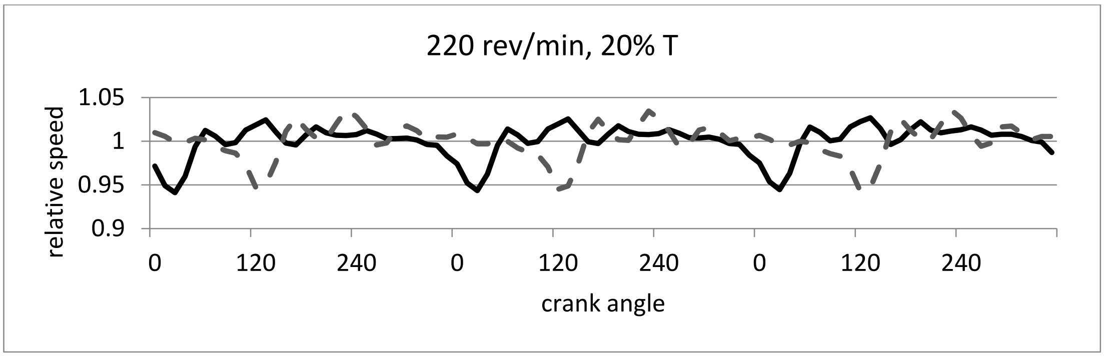

Fig. 4. Fluctuations of relative Instantaneous Angular Speed under 20% of load and 220 rev/min.

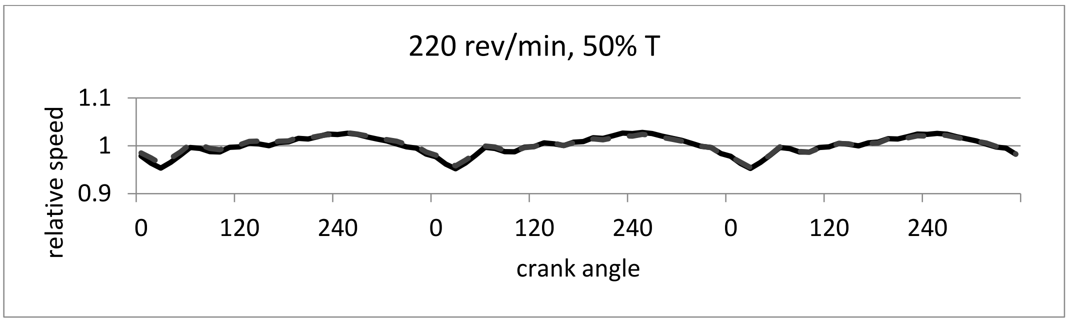

Fig. 5. Fluctuations of relative Instantaneous Angular Speed under 50% of load and 220 rev/min.

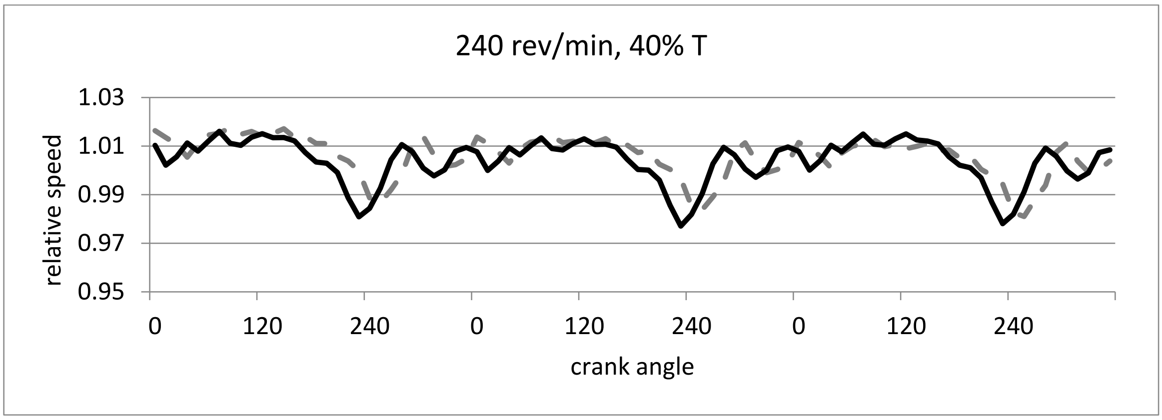

Fig. 6. Fluctuations of relative Instantaneous Angular Speed under 40% of load and 220 rev/min.

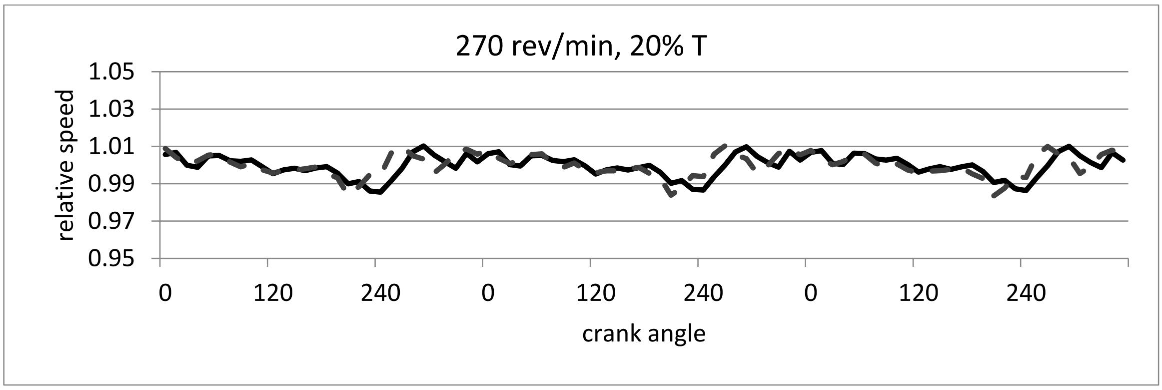

Fig. 7. Fluctuations of relative Instantaneous Angular Speed under 20% of load and 270 rev/min.

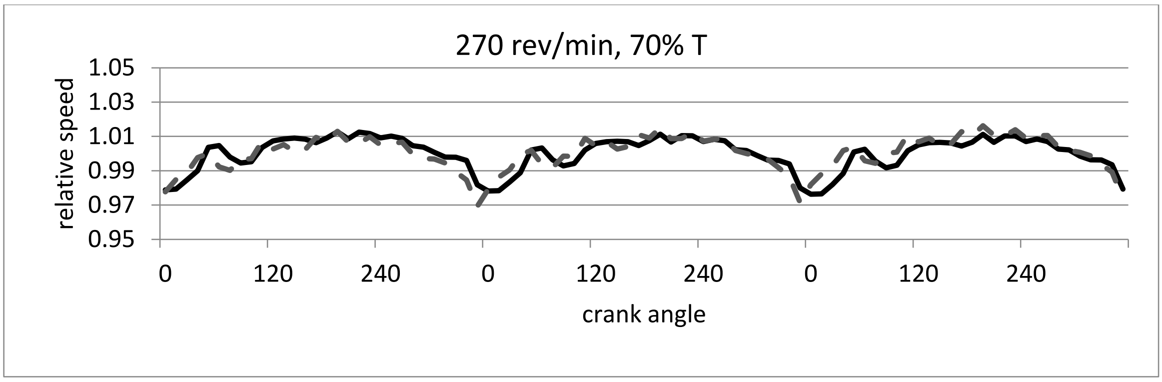

Fig. 8. Fluctuations of relative Instantaneous Angular Speed under 70% of load and 270 rev/min

The next step of analysis of diaphragm's influence at behaviour of engines parameters was comparison of instantaneous value of torque, measured with different loads and mean revolutionary speed. The tests were conducted with speed of 220, 250 and 270 revolutions per minute, and with load equal to 20%, 40% and 60% of nominal load. What is typical for one-cylinder engines, with a big mass flywheel, torque is oscillating around mean value, with relatively big negative value (Fig. 9). Accuracy of load setup depends of regulation of water flow through adjusting valves and is not possible to have 100% recurrence.

The values of torque adjusted with and without diaphragm were respectively: 211.2 Nm and 219.2 Nm for 20% load and 220 rev/min; 220.9 Nm and 231.1 Nm for 270 rev/min and 20% of load; 493.8 Nm and 521.3 Nm for 240 rev/min and 40% of load; 714.2 Nm and 698.9 Nm for 270 rev/min and 70% of load.

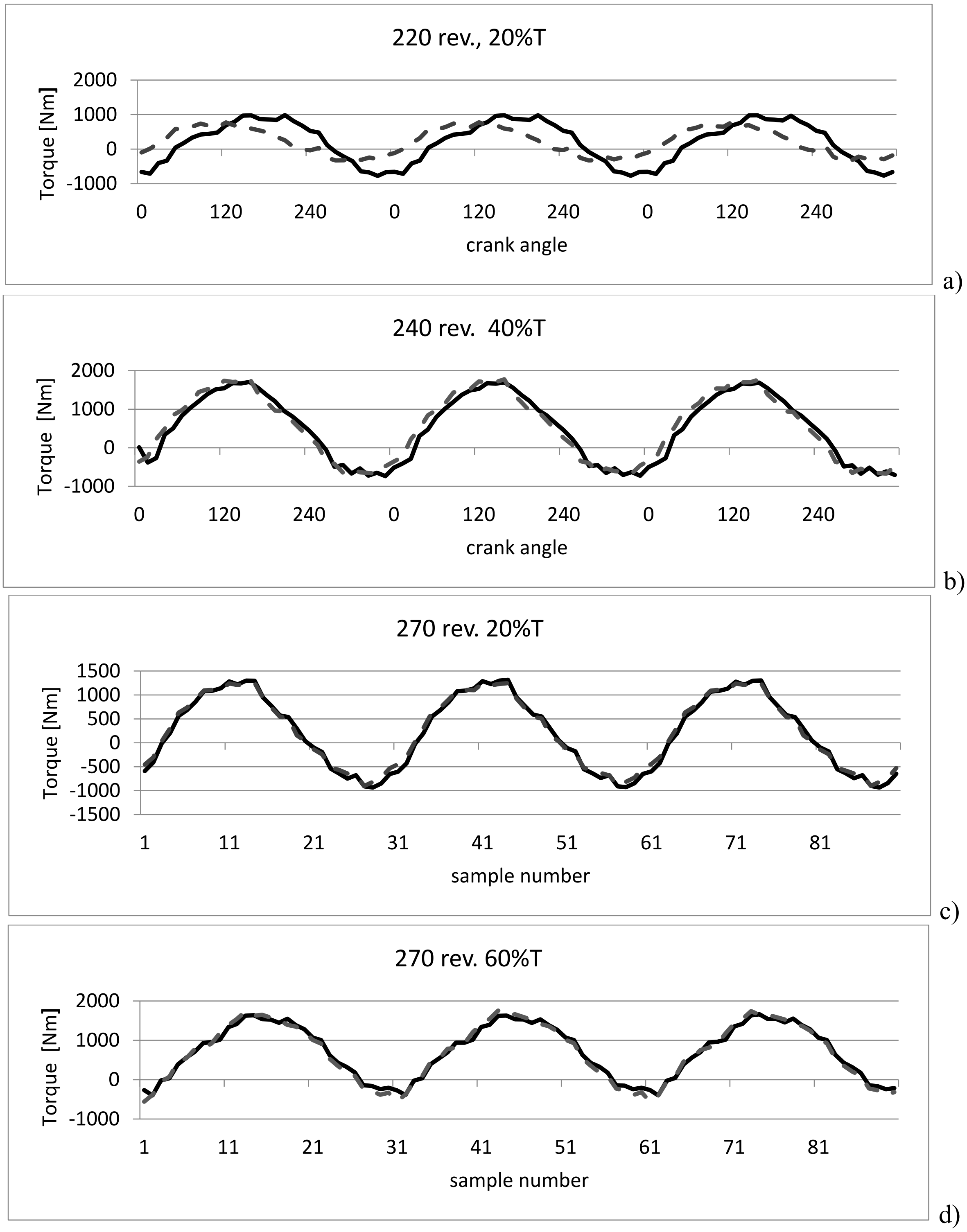

Fig. 9. Comparison of runs with and without diaphragm of instantaneous torque value in conditions of different load and revolutionary speed

The picture of torque curves presented at Fig. 5 shows that in low load and low revolutionary speed, the diaphragm created phase shift between and difference between magnitudes, although mean torque value span is only 5%. One has to see that shift of phase occurred for speed curves as well (Fig. 4). When speed and load were increased, span phase shift was significantly reduced (Fig. 9b). Torque curves runs when speed reached maximum value 270 rev/min shows lack of influence of diaphragm, even load was only 20% of nominal (Fig. 9c). The same situation occurred when load was high (60% of nominal), what is presented in Fig. 9d.

Conclusion

Results of conducted tests and subsequent analysis of obtained results let come to general conclusion that influence of additional resistance of exhaust gases flow, created by diminishing of crossection area of gas pipe is low when engine is working at normal, load what means, for marine engines, 60-90% of nominal value. Probably the length of exhaust piping lets compensate diminished diameter. Results of measurements show that both, instantaneous angular speed and instantaneous torque are not changed. What is interesting is fact that even under low load, torque and speed runs are not changed; under condition, that angular speed is higher. It can be due to higher inertia of flywheel, giving very important contribution to piston dynamics of single cylinder engine.

Completely different picture was obtained when low speed and low load case were analysed. Both curves, instantaneous torque and speed presents phase shift between runs with and without diaphragm. It can be caused by worse conditions of scavenging because of higher resistance of gas flow through exhaust pipe.

The last conclusion coming from carried out experiment is that optical sensor and discs mounted at the shaft are good and sensitive tool for monitoring of crankshaft dynamics. That method enables measuring and recording even small deviation of torque and angular speed from normal run. Analysis of above deviation gives a possibility to undertake diagnosis about engine condition.

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