INVESTIGATION OF THE INTEGRATED POWERTRAIN ON THE DYNAMOMETER STAND

Mirosław Karczewski, Leszek Szczęch, Jerzy Walentynowicz

Military University of Technology
gen. S. Kaliskiego Street 2, 00-908 Warszawa, Poland
tel.:+48 22 6839546, fax: +48 22 6839546
e-mail: mkarczewski@wat.edu.pl, lszczech@wat.edu.pl, jwalentynowicz@wat.edu.pl

Abstract

Description of the test stand for investigation of the integrated powertrain (powerpack) for armoured modular vehicle (AMV), disassembled from vehicle, is presented in this paper. The powerpack unit consist of a diesel engine, a gearbox and a cooling unit with a hydraulic fan drive. The stand is equipped with measuring devices for torque measure, fuel consumption, exhaust smoke and exhaust gas components emission analysers. The powerpack has been loaded by a hydraulic dynamometer of power range up to 1250 kW. It is dynabar water dynamometer with high dynamics of load changes. For control the motor and drive, system the original control panels from the vehicle was used. The original start-up unit, mid fuel tank and air filters were used too. Research on the powerpack unit was made in the steady state versus the engine load and speed. The parameters of the engine and exhaust components were measured and compared with the catalogue values. Two modes of engine work were compared – economic and dynamic modes. Those differences between two modes are result of maximum fuel consumption decreasing. The parameters of engine work were comparable in middle and low range of engine load. On the stand investigation in transient states during free engine acceleration were made. It was found that additional load of engine is too high and this problem should be clarified.

Keywords: *combustion engine, dynamometer stand, integrated powertrain*

1. Introduction

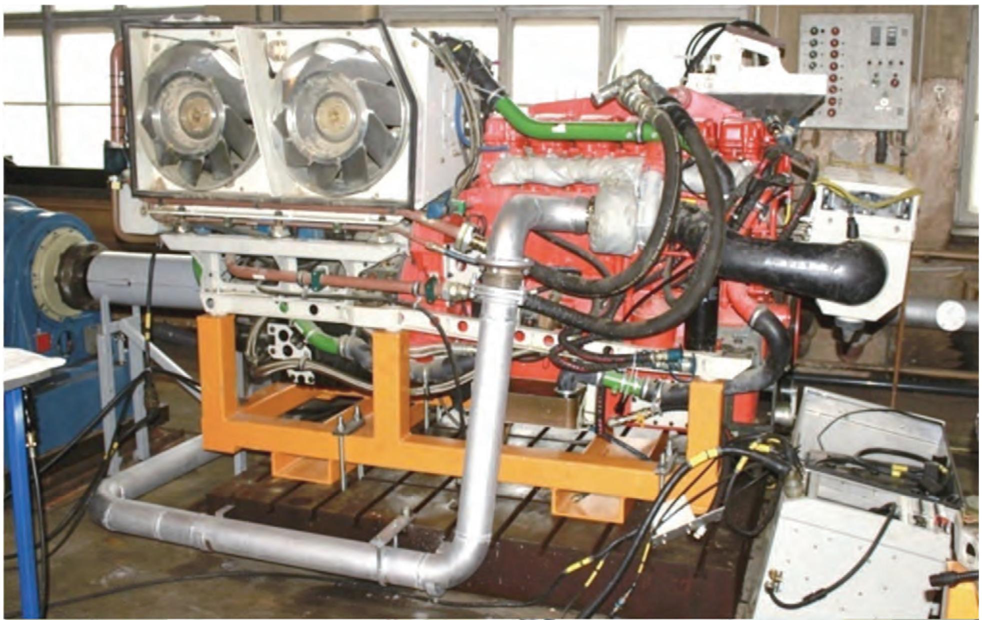
Dynamometer stands are used for internal combustion engines investigation in all range of speed and load. Those terms were used during exploitation of reciprocating combustion engines. Powertrain units in modern vehicles in common are integrated in one piece, and they consist of a combustion engine, a gearbox and a cooling system. It let too easy change all of powertrain unit in case of damage. Investigation of the powertrain unit demand to use of a dynamometer stand with large torque with low speed characteristic of outlet shaft of a gearbox. Initial analysis let to appreciate possibility of investigation of the integrated powertrain on the dynamometer stand with maximum power, three times bigger than maximum power of investigated engine. However low internal resistance of the dynamometer let to reach wide range of the engine load.

Main aim of presented paper was description of results of the integrated powertrain (Powerpack) investigation on the dynamometer stand in range usable parameters and toxic components of exhaust gases measuring during work in economic and dynamic (combat) state. Speed and load characteristic of the powertrain engine were showed. Results of operation in economic and dynamic state were compared.

2. Investigation stand

The test stand, where investigation of integrated powertrain were led, was equipped with dynamometer to load powertrain and all supported systems to exhaust gases, air induction, fuelling and fuel consumption (Fig. 1a). Close to the stand in a control room instruments for storing measured value and to the engine control were located. On the dynamometer stand, it is possible to investigate only the engine without gearbox and cooling system. During investigation an engine without powertrain, longer shaft is needed to connect the engine, the dynamometer and external cooling system, which is showed on Fig. 1b. The engine or the Powerpack (powertrain) is located on the dynamometer stand on a transportation cart after wheel dismantle.

a)



b)

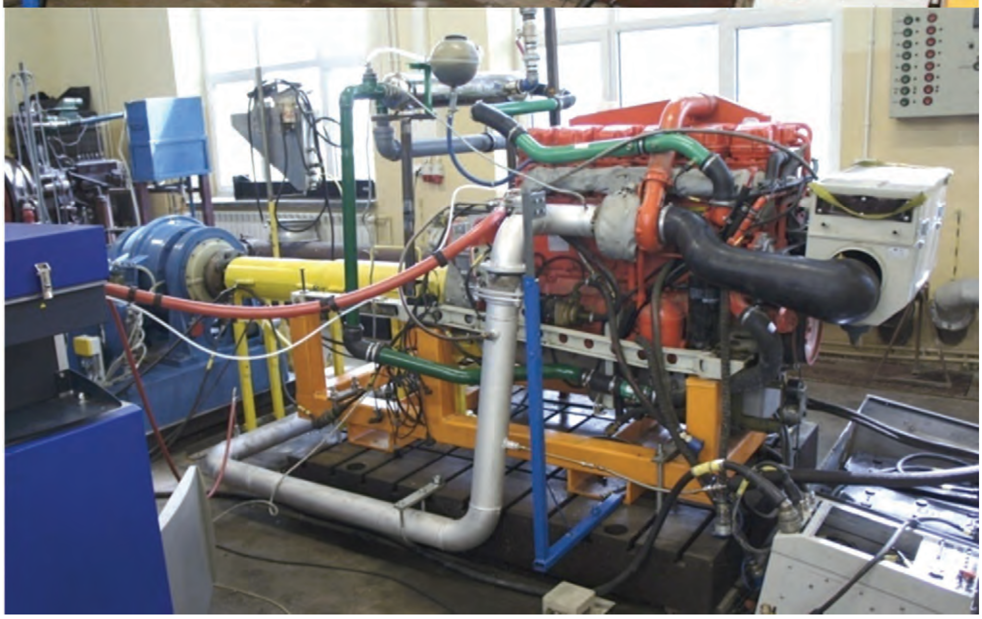


Fig. 1. The dynamometer stand: a) with Powerpack (power-train), b \) with the engine only

The basic unit of the stand is a dynamometer brake Zöllner PS1-3812 type (Fig. 2). It is dynabar water dynamometer brake with 1250 kW of power; its load may be controlled by filling brake chambers with water. For a proper work, the dynamometer should be supplied with steady pressure water. Water produce torque and cooling the dynamometer. Because the dynamometer need about 30 m^3/h of cool water (temperature lower than 30^{o}C) was connected to closed loop of supplied water equipped with a cooling tower with power about 2000 kW.

The dynamometer is equipped with two water valves. The first valve is located in the outlet tube and is used for torque regulation. Second one is located on the inlet tube and let to stop water flow and maximum diminish of dynamometer internal resistance torque. Cooperation of both valves four times increases of dynamic load change of the dynamometer.

a) b)

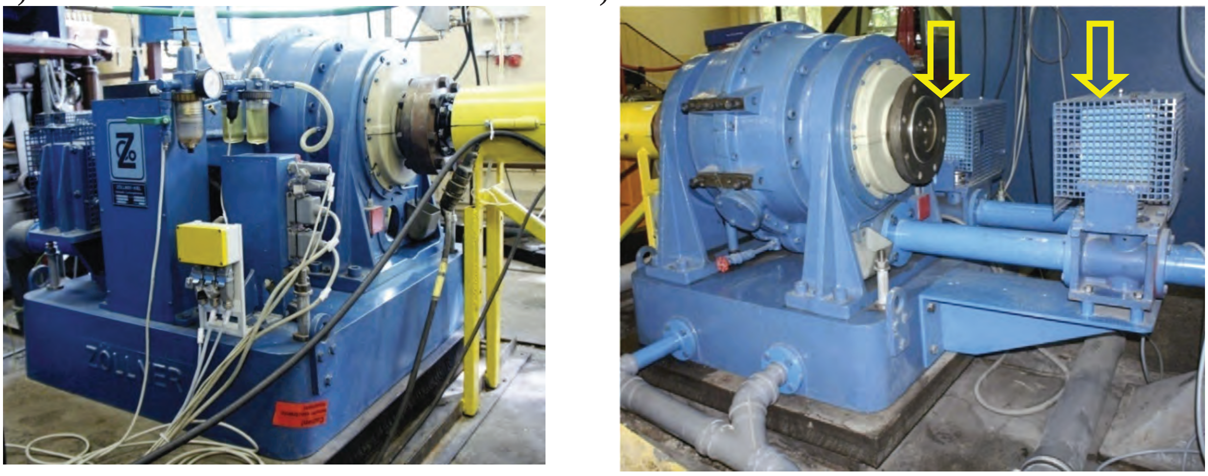


Fig 2. The Zöllner PS1-3812 dynamometer: a) side of controllers, b) side with water inlet and outlet valves

The dynamometer stand is equipped with measuring and control devices for measure fuel consumption, smoke and toxic gases components emission.

The engine and the dynamometer controlling is going from control cabin (Fig. 3). For the engine control were used control panel from AMV vehicle. It considerably fastened of the stand built.

a) b)

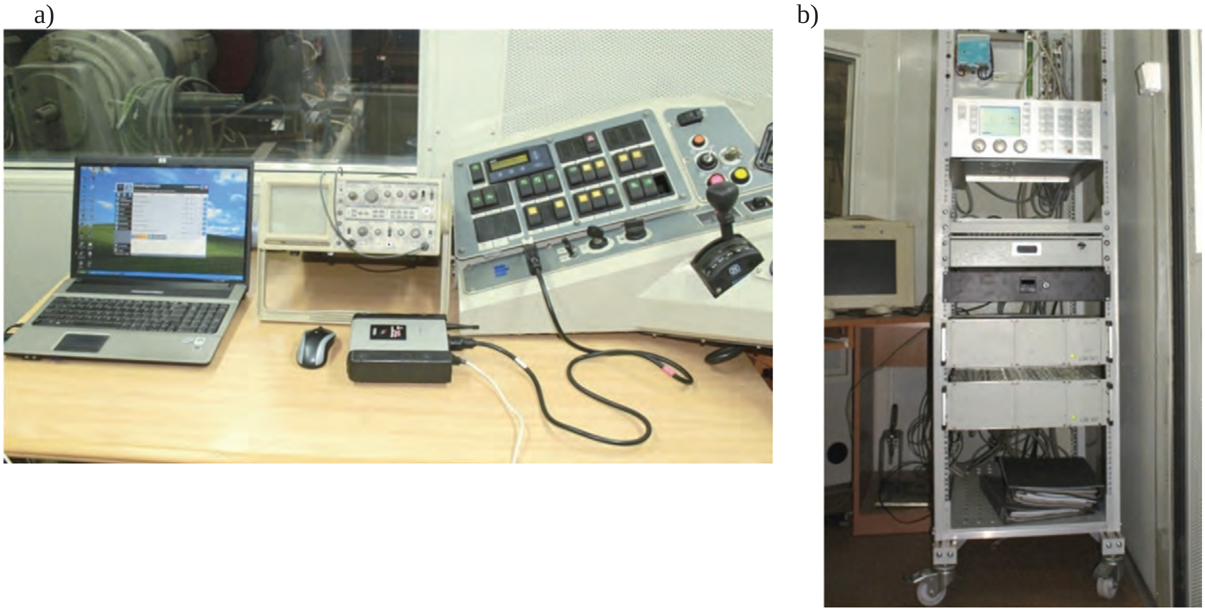


Fig. 3. Control units: a) the engine control system (driver panel), b) the dynamometer control system

3. Investigation of integrated powertrain in steady states

Investigation of integrated powertrain were led on the dynamometer stand in steady and unsteady state of the engine. There were determined speed and load characteristics of the engine in two – economic and dynamic (combat) – states of the engine work (Fig 4). External characteristics were done in rotational speed range 1300-2100 rpm. After switching control switch of the engine work to the dynamic state the engine power reach 330 kW. In economic state maximum power was only 260 kW. In compare to maximum power appreciated by producer measured power were about 9% less, but the engine were loaded with gearbox and powering cooling system with two fans. Therefore may be appreciate that the engine developed proper usable power.

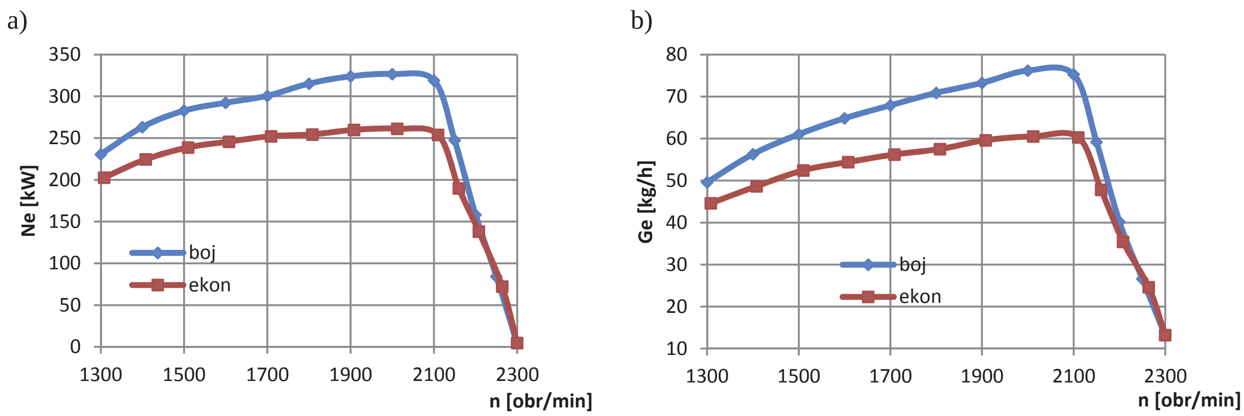


Fig. 4. External characteristics of the DI-12 engine: a) the engine power, b) fuel consumption

The engine was equipped with two work states i.e. economic state and dynamic state called combat state. It cause a big difference of the engine work parameters with maximum load in all speed range. Maximum rotational speed was 2100 rpm and minimum rotational speed on the second drive was 1300 rpm. Difference of maximum power with the engine speed 1900 rpm between two states reach about 20% (Fig. 4a) it was caused by 20% diminish of fuel consumption.

The result of difference of fuel consumption was increasing temperature of exhaust gases of about 50°C in all range of speed of the engine (Fig. 5a). In the same time pressure of air in inlet tube after compressor, about 0.2-0.3 bar (0.02-0.03 MPa) in the result of higher temperature and the same enthalpy of exhaust gases. Disadvantageous effect of fuel consumption increasing is increasing of smoke in almost all range of rotational speed. In range of 1800-2100 rpm exhaust gases smoke increased even 2.5 times (Fig. 5b).

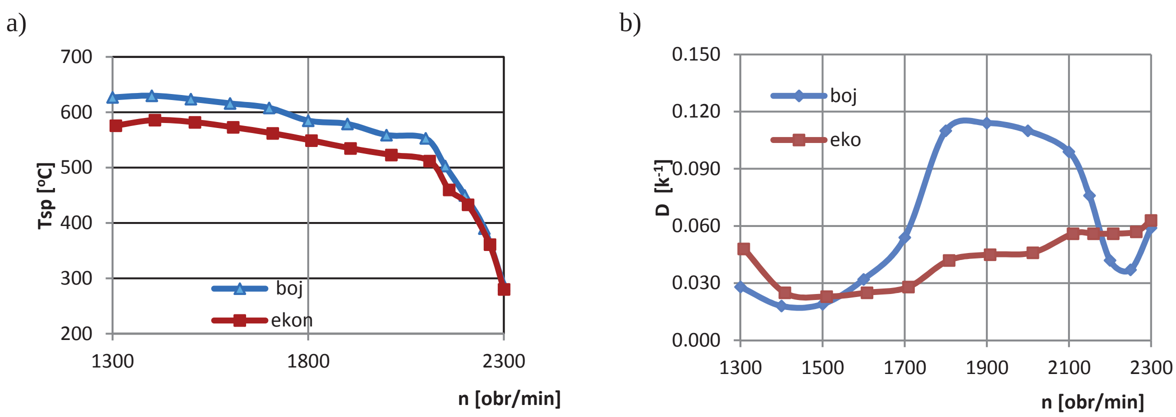


Fig. 5. External characteristics of the DI-12 engine: a) exhaust gases temperature, b) exhaust gases smoke

Increasing of maximum fuel dose and charging pressure caused increasing nitrogen oxides ratio in exhaust gases. Increasing reach 180 ppm with low speed of the engine to 100 ppm with nominal speed. Differences between this components ratio systematically diminish when rotational speed increased (Fig. 6b). Little less are hydrocarbons ratio in the high range of the engine speed, above 2100 rpm, after usable range of speed. In the range of 1600-2100 rpm, differences of hydrocarbons ratio were less (few ppm). In the range above 1600 rpm hydrocarbons ratio was the same in both states of the engine work. Carbon monoxide ratio in exhaust gases were comparable independence of the engine work state in range 60-80 ppm.

Lines of load characteristics confirm that difference between both the engine states is caused only by maximum fuel dose change. When the engine load is less all lines are comparable. It is visible on example of load characteristic appointed during work with speed 1400 rpm (Fig. 7 and 8). Lines of fuel consumption were strictly the same. Temperatures of exhaust gases were comparable and very low differences may be caused by difference of air temperature. Change of the engine work state was no influence on fragile work parameters as air charge pressure or nitrogen monoxide ratio.

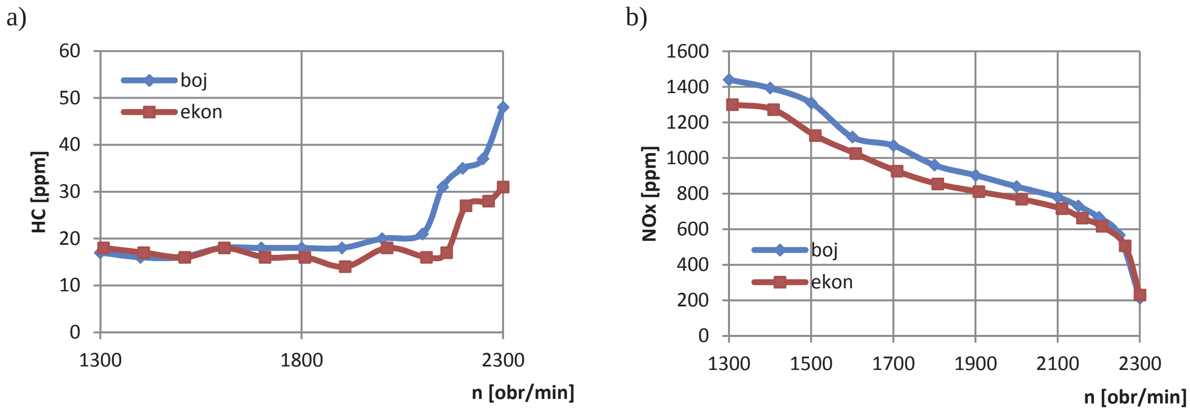


Fig. 6. External characteristics of the DI-12 engine: a) hydrocarbon ratio, b) air pressure after compressor

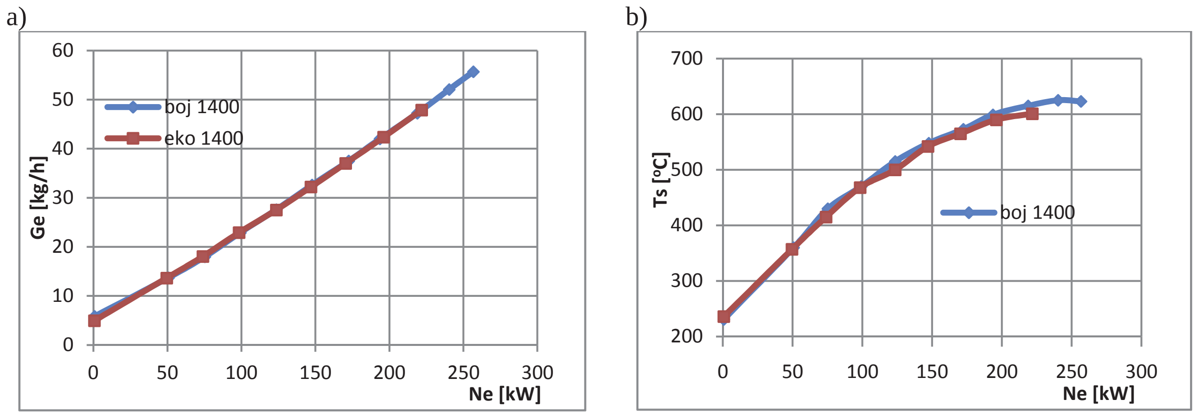


Fig. 7. Load characteristics of the DI-12 engine with rotational speed 1400 rpm: a) fuel consumption, b) exhaust gases temperature

Presented results of investigation showed, that difference between both the engine work states is caused only by difference of maximum fuel dose. It is interesting why these two states were introduced to the engine controller. What for is implemented engine work state with less maximum fuel dose? Which driver of AMV will drive his vehicle on economic state of the engine work with powerless about 20%? Is slower speed of vehicle reasonable? The only reason may be necessity of reach Euro 2 level of toxic components emission and exhaust smoke. Probably it is connected with nitrogen oxides which emission in dynamic state is more higher. That demanding were in auction documents of AMV buying. Passing of this demands caused on diminish of the engine maximum power.

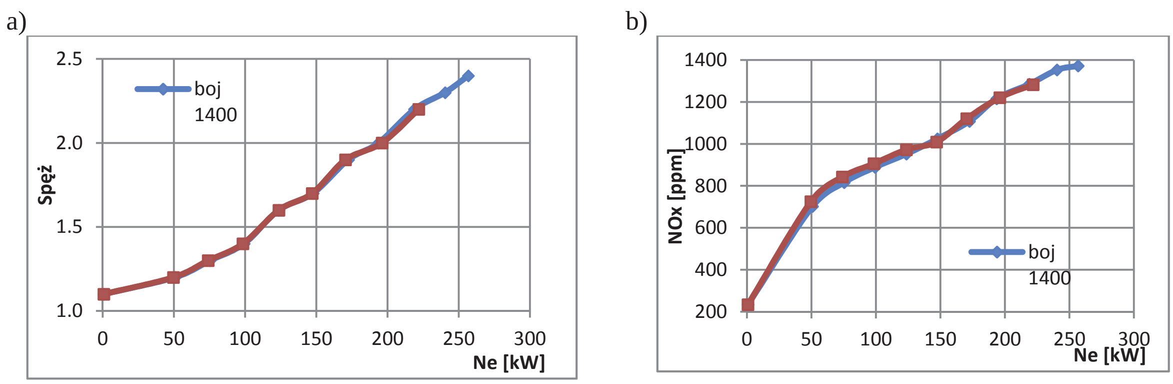


Fig. 8. Appointed load characteristics of the DI-12 engine with rotational speed 1400 rpm: a) air pressure ratio, b) nitrogen oxides

4. Investigation of the integrated power-train in transient states

Commonly used an engine diagnostic method are measuring parameters of free speed acceleration. At the time an engine is loaded only by inertia momentum of rotational parts and internal systems of the engine. It cause short work of an engine with maximum load and maximum fuel dose. This method is used during investigation of exhaust gases smoke emission in European test ELR (European Load Response). That investigation were led on the dynamometer stand with the DI 12 engine. Water flowed trough dynamometer brake was stopped. Measures of engine work parameters were led with many acceleration and deceleration of engine speed from 700 rpm to 2300 rpm (Fig. 9).

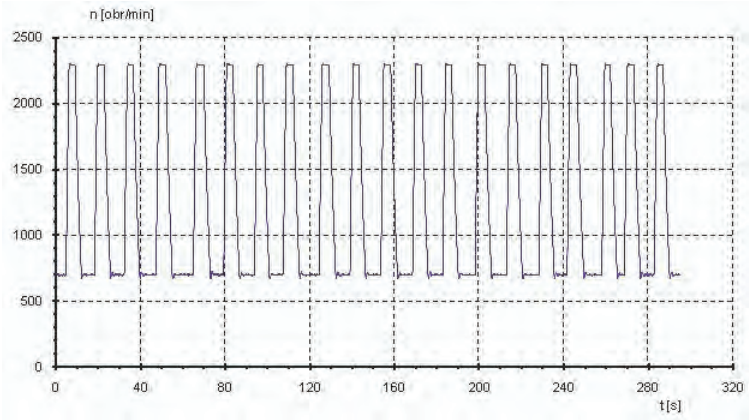


Fig. 9. Changes of engine speed in versus time during free acceleration

Results of investigation in shape of torque change characteristic is showed on Fig. 10. The engine torque appointed used measured change of engine speed and resistance of movement.

Several times repeated easy increasing of rotational speed was characterized by very good repetition and regularity. However, it is difficult to compare characteristics appointed in steady and unsteady conditions of the engine work. Maximum torque was measured with speed about 800 rpm and was equal 2200 Nm. Maximum torque measured during work in steady condition was 2000 Nm in engine speed 1400 rpm. With high probability, it is result of higher internal resistance of the engine and the dynamometer. It is visible as high negative moment also, higher than 1000 Nm in high range of engine speed. This high internal resistance moment should be verified by using an engine only without gearbox, cooling system and connection to the dynamometer.

The practical using of the acceleration characteristics for diagnostic purposes will be possible after specifying influence of various failures, which may change lines of the registered characteristics.

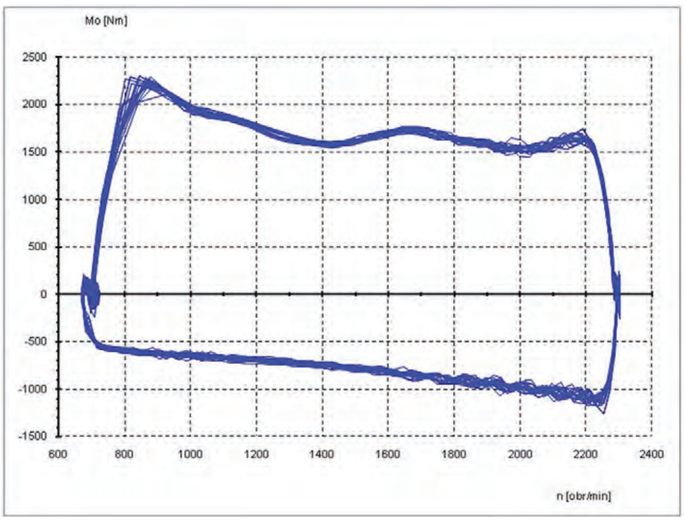


Fig. 10. Changes of engine load versus time during free acceleration

5. Conclusions

1 Designed and built dynamometer test stand allows conducting research in high-performance engines throughout the range of engine speed and load, including integrated propulsion systems of AMV.
2 On the stand can be carried out the tests of same engines and the integrated propulsion systems including gearbox and cooling system. For this purpose, matching units were made for an equipment installation and the units hold the engine on the test stand. This concerns first of all the framework for placing the engine on stand frame and an elongated shaft for connection the brake and motor instead the gearbox. It was necessary to change the cooling system also. Instead of cooling air heat exchangers was used the cooling water – water system supplied water from laboratory cooling system.
3. Engine test can be carried out both in steady state and transient. Water dynamometer is applied with additional devices that allow for more dynamic loading the engine. This option will be tested during next investigation.
4. A comparison of the results of measurements taken for the economic and dynamic mode of engine operation was state that the mode changes is made only by increasing the maximum fuel consumption without affecting other engine control parameters. In the mid and low range of engine torque, engine work parameters were similar for two mode of engine work.
5. The measure results showed that the test drive system does not differ significantly with respect to the parameters of other engines used for the propulsion wheeled transporter. Since this was the engine damaged during combat operations must be noted that after repairing the engine is technically proficient and can be installed in the vehicle.

Acknowledgement

Work funded on science in years 2009-2011 as a development project.

References

[1]. *Zöllner Performance Testing Device with Hydraulic Dynamometer Type PS1-3812/AE. Operating Instruction*, Zöllner GmbH, Kiel 1995.
[2]. *Wheeled Armoured Vehicle 8x8 Rosomak. Description and Opration*, WZM S.A. Siemianowice 2005.
[3]. Karczewski, M., Koliński, K., Szczęch, L., Walentynowicz, J., *Dynamometer test stand for estimation of technical state of propulsion system for AMV Rosomak*, in Monography: *Technologies of dual application*, MUT, Warsaw 2012.