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TESTING METHODOLOGY OF SMALL UNMANNED PLATFORM ON THE CHASSIS DYNO

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Abstract

The article shows construction solution of chassis dyno, designed for small-unmanned platform hybrid drive testing. Brief fore design of chassis dyno were also presented. Most important parts of dyno are module design of dyno. Each of dyno module consists of one free roll and one roll powered by electrical engine for inertia braking. Asynchronous electric engines for dyno stand were selected. Maximum torque, with respect to vehicle wheel torque has to be greater than Mo < 50 Nm, maximum linear speed of vehicle can't be greater than Vp ≤ 40 km/h, minimal vehicle dimensions: axle base greater than 500 mm, wheel base greater than 770 mm, inverters allow to connect in series enable synchronous operation by computer, during tests, received energy is dispersed in resistors, emergency shut off of each engines. Methodology of measurements, based on UDC test, was presented. Dyno stand was used for hybrid propulsion testing of small-unmanned vehicle. Dyno was used for hybrid drive testing, where measurement of electrical parameters, proportional to load of vehicle drive system, were collected and other parameters such as battery temperature, and electric engines or fuel consumption during tests. Tests were performed during various load and speed of vehicle. The developed methodology of research should allow for a comprehensive study of this type of vehicle in terms of overall efficiency, reliability and energy needs.

Keywords: *transport, road transport, simulation, dyno chassis, examination of unmanned vehicle*

1. Introduction

Nowadays, electric and hybrid vehicles are more and more often used in military operations, held by many countries, including Poland. Those vehicles are used as a recognition vehicles, transport or tactical support of single soldier or subdivision. Despite, electric and hybrid vehicles are minor part of all kind of vehicles used by military or police actions on a global scale and yet are not competitive to combustion engine vehicles, in the near future, it is expected to play significant role. This interest is made by its advantages – secretive approach to opponent, lack of clear thermal spectrum and noise emission make those vehicles difficult to detect.

Significant problem during use of those kind of vehicles in military actions is to know their traction characteristic in respect of use of electric energy and fuel, range or dynamic properties. It is complex problem and requires considering many factors, occurring beyond vehicle operation stage. During examination of electric cars, it is used EKG ONZ no. 101 regulation procedure. Vehicles are examined on a typical chassis dyno during NEDC test, to simulate driving urban condition and outside [2, 3].

Consumption of Energy by vehicle depends of traffic condition and vehicle parameters. Consumption of energy is determined by vehicle speed and external conditions such as rolling resistance, elevation, wind speed, etc. Because of those conditions, both fuel consumption and emission is evaluated like for classic vehicles.

During examination of electric and hybrid military vehicles, problems are caused by use of classic chassis dyno. It is connected with vehicle construction. Most cases 4x4 or 6x6 vehicles with compact construction are introduced, excluding use of typical chassis dyno, enabling examination only one axis of vehicle.

Article present test stand and methodology of small-unmanned hybrid vehicle to use in urban areas. Vehicle was design and build in Combustion Engines Laboratory of Military University of technology.

Role of designed chassis dyno as a test stand is to create artificial conditions similar to the real, occurring in real vehicle motion. Dyno simulate external drag forces meet on a road. Stand enable to eliminate road tests, creating conditions to carry various tests of combustion engine, electric drive, vehicle control system, tests under load as on real condition [5, 7, 8].

Test held on a test bench enable to determine vehicle limiting parameters – torque, power and its characteristics depend of engine speed, acceleration, driving force, correctness of subassembly works, drags and power loss in power transmission.

Stand is fully adapt of hybrid vehicle testing designed in the laboratory of combustion engines. Stand take into account vehicle dimensions, torque, and power. Maximum linear speed was set to 40 km/h. Stand is designed for vehicles testing and is partly automated.

2. Construction solution of dyno

After deep analysis of the dyno stand similar solutions, decision of use reel test bench with modular structure was made.

Dyno chassis do not measure directly parameters of the engine, but its performance, based on quantities measured indirectly. In opposite to engine test bench, chassis dyno's are simple in construction and in use. They do not require unmounting engine from vehicle and build additional special systems for engine control. Precision of measurements of chassis dyno is high, also repeatability of performed tests. Slight measurement errors can occur during wheel spin on a reel.

Methodology of the test was elaborated to measure parameters of small-unmanned ground vehicle hybrid power transmission, designed in Combustion Engine Laboratory of Mechanical Faculty of Military University of Technology. Examination of the drive was earlier described in [2, 3 10]. Power transmission of vehicle is designed to provide high mobility and long range. Vehicle was designed to operate with the same speed on battery and with combustion engine turned on and enable to operate inside buildings.

Analysis result of possibility of use chassis dyno and its construction requirement, reel chassis dyno – load version was selected with individual induction electric engines, one for each wheel. Those engines can operate as a braking and drive mode of each wheel. Dyno stand was designed to examine whole vehicle (4x4, 6x6) and single axis (power and torque depend on speed, acceleration, driving force, resistance and loss in power transmission of the vehicle. Module design enable to examine other vehicles, due to modification in module set up, depending of wheel space of the examined vehicle.

Proper configuration and set up of elements, project brief fore design of dyno were made:

- modular structure – six independent, repeated modules (three left and three right) with possibility of wheel space change,
- each of module have one driving reel and one unbounded,
- one module is design as a dynamometer for one wheel,
- asynchronic engines were used,
- maximum torque can't be greater than $Mo \leq 50$ N·m,
- maximum linear speed of vehicle can't be greater than $VP \leq 40$ km/h (reel speed is then $n_r \leq 1000$ RPM),
- minimal dimensions of vehicle: wheel space greater than 500 mm, wheel track greater than 770 mm,
- maximum load of vehicle, $m \leq 375$ kg on each wheel,
- wheel base limited by length of modules connectors,

– one engine tor one module,
– engines are operated by inverters, responsible for speed adjustment and torque,
– one inverter is use to work with one engine,
– inverters enable to work synchronous,
– during tests, received energy is dispersed in resistors,
– emergency shut off of each engines.

Dyno stand was design to test small-unmanned vehicle (Fig. 1). Vehicle consist of three axis, each wheel of vehicle is driven by electric engine with maximum power P = 2.8 kW, total mass of vehicle is 400 kg.

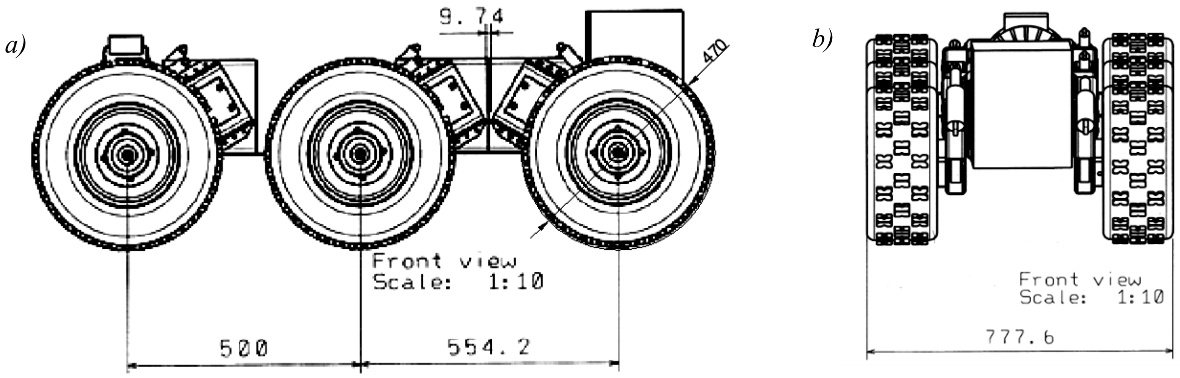

Fig. 1. Dimensions of unmanned platform a) side view, b) front view [9]

Realization of work required selection of each element of the stand. Most important elements are:
a) inverters – to operate with electric engines,
b) electric engines also working as a generators,
c) set of rolls.

Based on assumptions and working conditions, structure of stand was develop. Fig. 2 show essential elements, providing proper work of dyno.

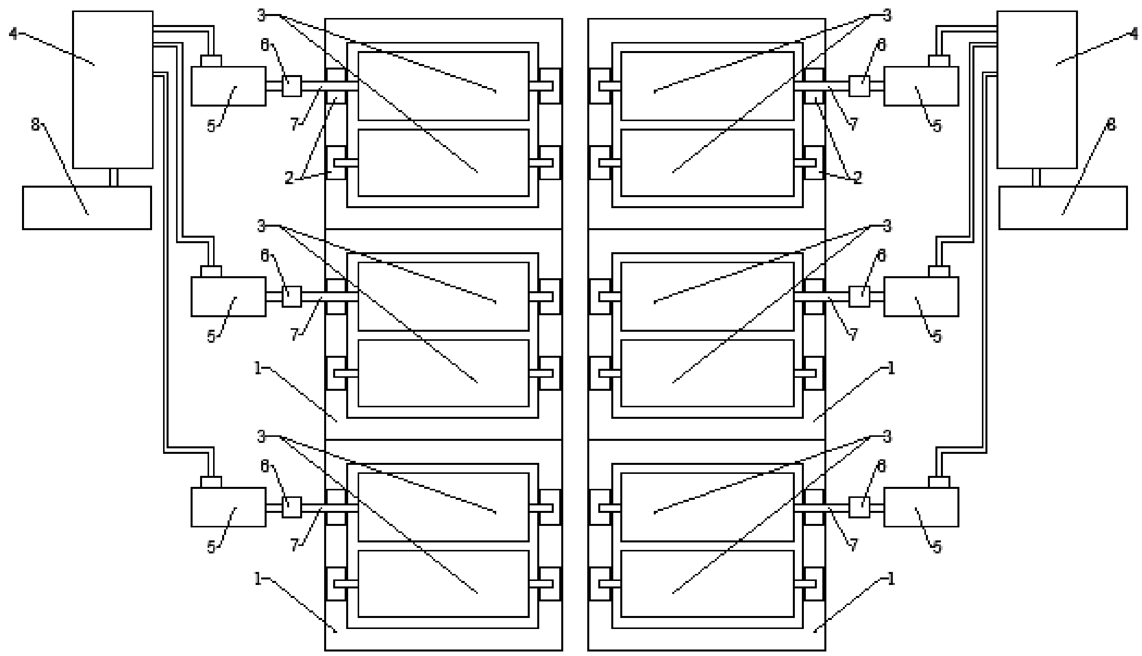

Fig. 2. Block diagram of designed chassis dyno: 1 – frame, 2 – bearings, 3 – reels, 4 – inverter, 5 – electric engine, 6 – coupling, 7 – power feed shaft, 8 – energy receiver [1]

Components of the chassis dyno stand can be divided on two groups:

- mechanical elements:
  - frame of a single module,
  - rolls,
  - bearings,
- electrical elements:
  - electric engine,
  - inverter,
  - brake resistor.

Frame of the module coupling all elements. Project of the frame of single module (Fig. 3a) depends of dimensions of other elements such as bearings spacing holding rolls, external dimensions of rolls, dimensions of engine. Frame is made of 100 mm channel bar.

a) *b)* *c)*

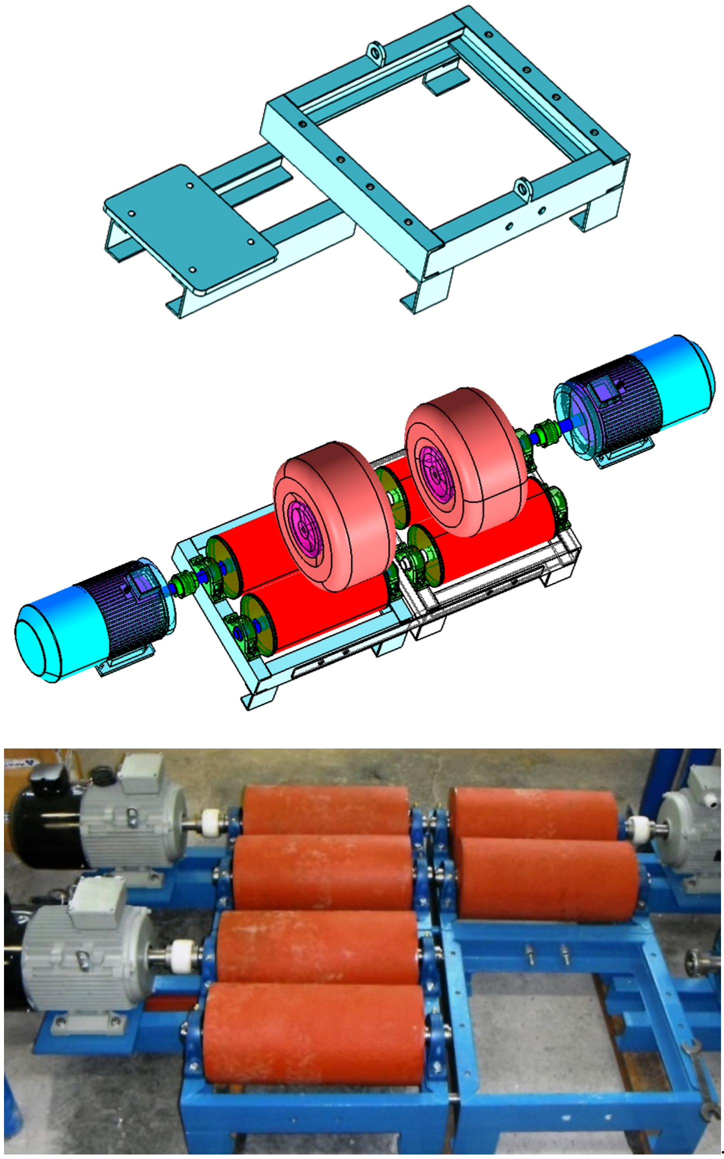

Fig. 3. Elements of the stand a) frame of one module of dyno with electric engine mounting base, b) dyno module for one axle testing – visualization of project, c) dyno assembly

Next element of the dyno are rolls (Fig. 3c) where wheel of examined vehicle is rolling. Those rools are made by steel and coated thin layer of non-skid corundum. Module enables examination of vehicle up to 40 km/h.

Rolling bearings in mounting were used to keep rolls and frame together. Bearings were calculated to take into account wheel load and speed of vehicle. Because of diameter of the roll shaft, bearings exceed minimal parameters of the load and speed. To connect shaft of the roll with engine, curved-tooth BOWEX coupling were used [1, 5]. Construction of the coupling is maintenance-free. Assure compensation of axial, radial and angular deviation.

Engine selection was made on the base of technical parameters of examined vehicle and other assumptions. Power of engine was calculated to P = 5.29 kW, that is why Indukta asynchronous engine with external cooling was selected. Engine speed is 1000 RPM and power P = 5.5 kW with Torque 55.3 Nm. Each engine was equipped by encoder for vector control [1].

Control of the vehicles is realized by inverter. Each inverter controls one engine. Inverters have function that enable braking. This is useful especially during tests with accelerating and decelerating of vehicle. During decelerating, engines works as a generators, produced energy is dissipated as a heat.

2. Test stand and testing methodology

Main scheme of test stand show in Fig. 4. During realization single stages of the stand, part of the equipment was changed and modified due to needs. Table one show measuring equipment – Fig. 4.

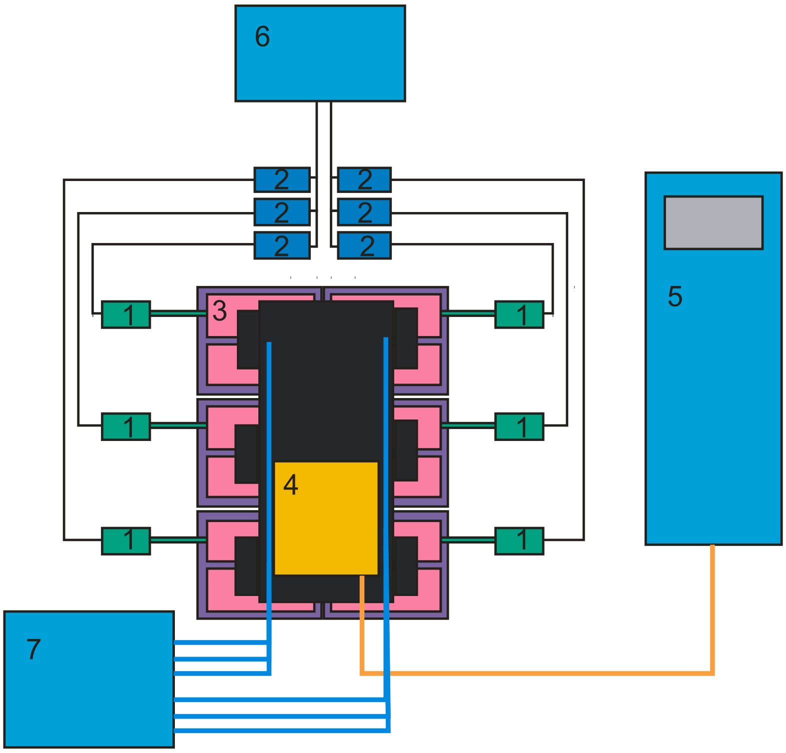

Fig. 4. Configuration of dyno stand during tests: 1 – electric engines, 2 – inverters, 3 – dyno stand, 4 – power generator, 5 – exhaust gas analyser with registration, 6 – dyno stand operating computer, 7 – vehicle's parameters data recorder

Platform was equipped by sensors, measuring parameters of components:

- electric engines of the vehicle: current and voltage,
- vehicle generator: current and voltage on the outside,
- vehicle inverter: supply current and voltage,
- battery: current and voltage,
- vehicle wheel speed,
- power generated by individual wheel of the vehicle: measurements with use of vehicle inverter.

Tab. 1. Measuring equipment used during tests

No.	Measuring device / measured quantity	Type	Range	Accuracy
1.	Vehicle wheels speed– n	Encoder OEW2-1024-2MHT	n = (0-4000) min^{-1}	± 1 min^{-1}
2.	Current signals – current clamps	TiePie Engineering	(0-80) A (0-600) A	± 0.001 V/A ± 0.005 V/A
3.	Voltage signals	MSX-E3011	(0-10) V	± 0.001 V
4.	Fuel mass, hourly fuel consumption – G_e	AVL 733S Fuel Balance	(0-200) kg/h	± 0.005 kg/h
5.	Exhaust gas analyzer – measurements of toxic compounds concentration in exhaust gas – carbon dioxide (CO_2), – hydrocarbons (HC), – carbon monoxide (CO), – nitrogen oxides (NO_x), – oxygen (O_2).	AVL CEBII	CO_2 (0.01-23)% HC (1.0-2200) ppm CO (1.0-11000) ppm NO_x (1.0-6000) ppm O_2 (0.1-21)%	± 0.1% of measured quantity

Furthermore, internal systems enable to measure:

– hourly fuel consumption,
– exhaust gas emission.

Acquisition modules were placed on the top of the vehicle and connected to sensors. Data transfer was executed by TCP protocol to the router and connected PC class computer wit installed and configured database. Database enables to acquire data send by acquisition modules and placed in database.

Speed of the vehicle wheels were read out by Nemicon OEW2-1024-2MHT encoders [5]. Encoders were connected with digital Acquisition ADDI-Data module MSX-E1701 [6]. Second type of acquisition modules is analogue module MSX-E3011. Those modules enable to measure 16 parameters simultaneously. For measurements, three modules were used, serial connected together with digital module. All modules were supply from DRP-240-24 power supply.

Current parameters were measured with use of current probes. Depends of the current range, different probes were used. Maximum current occur between battery and junction box, providing voltage to inverters. Here was used CC-600 Tie Pie Engineering probe.

Test were holds of dynamometer stand described above, according to ECE R15 test, used for vehicle homologation. Speed range of test was set with respect to maximum speed of vehicle.

Procedure of the control of vehicle and dyno was managed by computer algorithm, especially implemented to this type of test. Examination were held is three stages, depending on hybrid drive mode:

– vehicle's engines feed from battery, combustion generator turned off,
– vehicle operate both battery and combustion generator,
– vehicle operate on generator, combustion engine turned on, battery turned off.

Examination on dyno chassis is carry by real vehicle and procedures of accelerating and decelerating are made by staff. Margin of error during test vary between ±2 km/h.

Work cycle of the unmanned vehicle on the dyno stand and dyno stand, was controlled by computer with converted speed value to the electric engines speed. Algorithm enabled to perform tests in similar conditions to the ECE R15 test.

Test performer on chassis dyno take into account gearshifts and vehicle acceleration. On the stand, gears shifts were simulate by reducing engine speed and unloading.

During tests, exhaust gases were analysed in CEB II-2000 analyser that enables on-line measurements of exhaust gas components. Values of gas components were given in ppm. It was possible to determine separate component of exhaust gas of working combustion engine.

3. Summary

Elaborated test stand is fully adapter for hybrid vehicle examination, developed in Laboratory of the Combustion Engines. Stand respect vehicles dimensions, electric engines torque. Accepted maximum linear speed during tests is V = 40 km/h. Dyno chassis is fully value installation for vehicle control, mostly automated stand.

Performed tests, verification and recognition, entirely confirmed correctness of assumed brief fore design of the test stand. Stand enable test performing of the small-unmanned vehicle in different working conditions.

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