EXPERIMENTAL METHOD OF DETERMINING CHARACTERISTICS OF POWER AND TORQUE ENGINE FOR LOW-POWER UNMANNED AERIAL VEHICLES

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Abstract

The article presents an analytical determination of power and torque of internal combustion engines of small power. It measured actual power and torque characteristics of internal combustion engines of small power. Three types (methods), braking (receiving power via a hydraulic pump, generator and a package of propellers with variable angle of attack. For each method of receiving power (braking) determined the characteristics of torque and power. There is the summary of results for one engine with different ways of braking. There have been evaluation of the presented methods inhibit combustion piston engines of small power as methods for determining power internal combustion engines. The analysis methods presented in the perspective of the braking engine selection for light unmanned aircraft, and the use of parameters derived from research into engine control. Subject to the evaluation method of adjustment (increase) charged, increasing the load on a liquid or ankle. The criterion for comparing methods for inhibition of internal combustion engines of small power load assumed dependence on the rotational speed n, and obtain maximum power on the motor shaft when the throttle, a reflection of the actual engine operating parameters in its target applications.

Keywords: *transport, internal combustion engines, motor test, motor braking*

1. Introduction

Unmanned Aerial Vehicle (UAV) or Vertical Take of & Landing unmanned aerial vehicle (VTOL UAV) is currently very dynamic nature of aviation. Along with the development branch or UAV VTOL UAV encountered a problem and the selection of its propulsion engines of sufficient power. Due to the specific characteristics of UAVs or UAV VTOL internal combustion engines used in them must have:

- low weight / power ratio - should produce high power at the lowest possible weight,
- pull cylinder arrangement, popularly known as the “boxer”,
- upper valves mechanism of motor control, even when the engine is so called “inverted system”.

Furthermore, internal combustion engines in the VTOL UAV or UAVs operate in diverse conditions in terms of weather conditions, temperature, pressure and oxygen content in the air. This causes the fast interrupt load conditions power plant VTOL UAVs or UAVs. Propeller is produce which is the main thrust of the engine power receiver. This determines the specific design and features used in UAVs and UAV VTOL engines.

Most of VTOL UAVs or UAVs used by a small internal combustion engines which have the following parameters: the power to 35 hp, torque to 40 Nm, the weight of the engine with the working fluid up to 35 kg. Currently, the VTOL UAV or UAVs is implemented internal combustion engines of the above parameters with the outside air applications. Manufacturers of combustion engines uses air from outside does not define the characteristics of torque and power produced by their engines.

Due to the nature of control and power unit load, or UAV VTOL UAV requires a thorough knowledge of the characteristics of torque and power are used in internal combustion engines. Determination of characteristics of internal combustion engines for use in a VTOL UAV or UAV is to place the engine complete with accessories on the bench, which allows any load on the engine and a precise measurement of power and torque for the engine throttle. Internal combustion engines shall be tested on a special bench in order to: research generated by the engine parameters (torque, power, and their characteristics depending on turnover), the adjustment during the measurement and the possibility of interference with the motor parameters, the study of toxic emissions, fuel consumption and emissions noise, etc. obtained in bench trials torque and crankshaft speed allows calculation of the internal combustion engine and determine the range of usable power and torque (operating). The term power of the engine allows the engine to match or UAV VTOL UAV on the optimum operating parameters (power, torque, rotational speed).

2. Theoretical determination of power and torque characteristics of internal combustion piston engine low power

Table 1 summarizes the results of theoretical calculations of power and torque engine OS-50 SXH Heli Max (tested on the bench) at the assumed speed of the motor shaft. To calculate the theoretical power and torque there are the theoretical equations (1), (2) and (3). To determine the theoretical power engine torque and power output, calculate Ne (effective), the torque Mo [Nm] received from the motor shaft, full of useful medium pressure.

Tab. 1. Summary of results of theoretical calculations

Speed n [rpm]	2500	4000	6000	9000
Torque M_o [Nm]	0.874	1.127	1.423	1.756
Power N_e [kW]	0.52	0.832	1.248	1.872

Power Output Ne (effective) is the received power from the motor shaft which is analytically determined using the dependence [1]:

$$N_e = \frac{2}{\tau} * V_{SS} * p_e * n \text{ [W]}, \tag{1}$$

where:
τ - discriminant workflow (4 - to four-stroke, 2 - for a two stroke),
V_{SS} - engine capacity [dm^3],
p_e - useful for the average pressure [kPa],
n - rotational speed of the motor shaft [s^{-1}].

Torque Mo [Nm] received from the motor shaft is determined using the formula:

$$M_o = \frac{V_{SS} * p_e}{\pi\tau} \text{ [Nm]}. \tag{2}$$

The average useful pressure p_e is determined from the formula:

$$p_e = \frac{\eta * \gamma_0}{g_e * \lambda * l_0} \text{ [kPa]}, \tag{3}$$

where:
η - overall efficiency of the engine,
γ_0 - specific mass of the feeling of indulgence in the air [kg/m^3],
g_e - specific fuel consumption in [kg/kJ],
λ - the coefficient of excess air (mixture),
l_0 - theoretical air consumption (constant stoichiometric fuel).

3. Experimental determination of power and torque of a piston engine exhaust low power

Measurement of the load for constant speed under the experimental designation engine torque and low power is to balance the driving force through the brake and engine power calculation based on data from the strain gauge (force sensor) and a tachometer (counter rotation). Measurement time is defined as the full load at constant speed (engine it will continue the stable operation point) for each measuring point (specifically selected throttle opening angle).

For the experimental determination of power and torque the engine can be substantially low power use, depending on the load of the engine, three solutions:

1) engine load with the brake hydraulic,
2) engine load with electric brake,
3) charging the engine with propellers of different aerodynamic characteristics (resistive).

The diagram of the load on the engine using a low power using hydraulic brake (using a hydraulic pump as a power receiver) is shown in Fig. 1

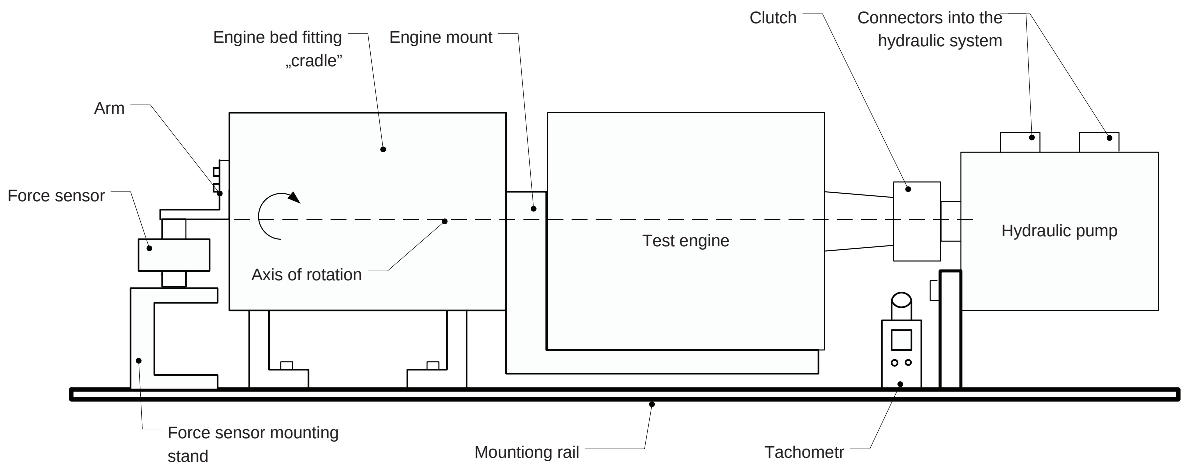

Fig. 1. Diagram of engine test bench using the low power of the hydraulic pump as a power receiver

Up and reaches the maximum speed by the combustion engine for the opening of the throttle is disconnected from the hydraulic brake (no load). After reaching a maximum speed of the internal combustion engine for a given throttle opening, shall be charged to it by throttling the flow in the line of hydraulic oils. The internal combustion engine to charge the crossing of the balance of power, which causes it to stop. The point of measuring engine torque, at constant speed to balance the torque and torque received by the brake hydraulic system. Power calculation engine for the opening of the throttle is based on data from the strain gauge (force sensor) and a tachometer (counter rotation). The result is a family of characteristics of the engine torque as a function of engine speed for different angles of the throttle opening. The characteristics of the engine maximum torque plotted curves connecting the tops of the family characteristics of the engine torque as a function of engine speed for different angles of the throttle opening.

Figure 2 shows the family characteristics of the engine torque as a function of engine speed for different angles of the throttle opening and the maximum torque curve. The curves shown in Fig. 2 have been plotted on the basis of experimental internal combustion piston engine type of low power OS Max 50 Heli SXH the view that uses the engine load by means of a hydraulic brake.

Result of measurement of engine power on the rig with a hydraulic brake (with load balancing in the motive power mode) is marred by an error. Error method of hydraulic brake motor load due to difficulties in achieving stable operation of the engine for maximum power at the throttle. The advantage of charging the internal combustion engine using low-power hydraulic brake fluid is a change in engine load.

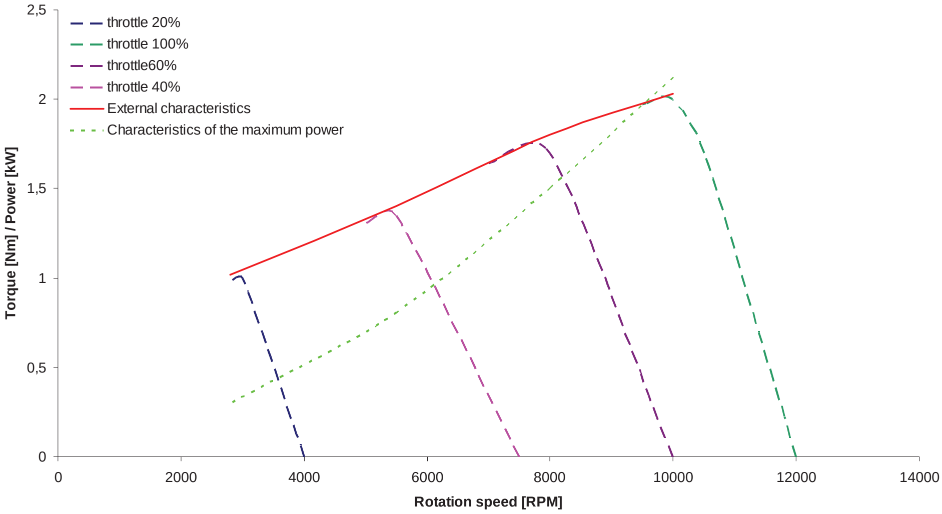

Fig. 2. Family characteristics of internal combustion engine torque versus engine speed for different angles of the throttle opening and the maximum torque curve - hydraulic brake

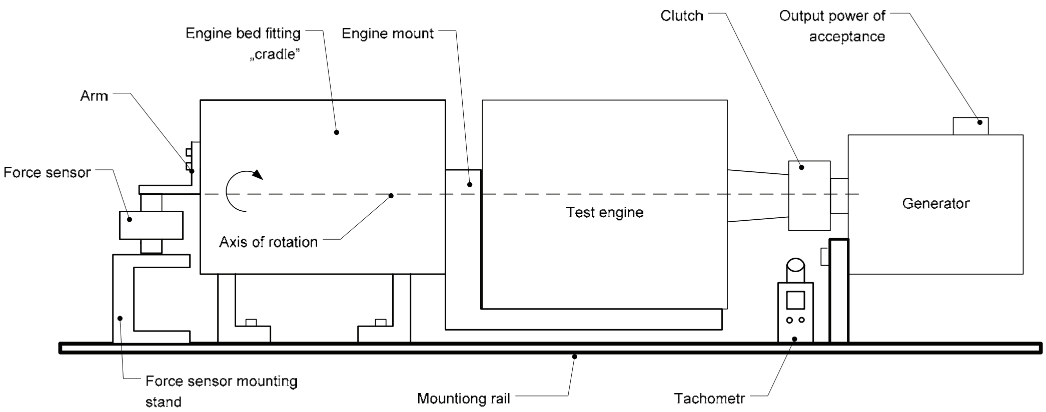

Fig. 3. Diagram of small power engine test bench, using a generator as a power receiver

The diagram of the load on the engine using a low power using an electric brake (using the generator as a power receiver) is shown in Fig. 3

Up and reaches the maximum speed by the combustion engine for the opening of the throttle is done with a progressive system of debiting the electric brake. Increased burden on the system of internal combustion engine and electric brake power loads (light bulbs) is associated with increased rotational speed of the shaft. Measurement of engine power on the rig with an electric brake (with load balancing in the motive power mode) can achieve stable operation of the engine at maximum power for a throttle. This is achieved through correlation of changes in electrical resistance under loads (lamps) on the turnover of the internal combustion engine. Increasing the electrical resistance of the power load increases and a drop in engine speed of the engine. This results in a smoother movement of the point of internal combustion engine to the point of balancing the speed of the electric resistance of the receiver power. Measurement of the load at constant speed is to balance the driving force using electric brake and engine power calculation based on data from the strain gauge (force sensor) and a tachometer (counter rotation).

The result is a family of characteristics of the engine torque as a function of engine speed for different angles of the throttle opening. The characteristics of the engine maximum torque plotted curves connecting the tops of the family characteristics of the engine torque as a function of engine speed for different angles of the throttle opening.

Figure 4 shows the family characteristics of the engine torque as a function of engine speed for different angles of the throttle opening and the maximum torque curve. The curves shown in Fig. 4 were plotted on the basis of experimental internal combustion piston engine type of low power OS Max 50 Heli SXH the view that uses the engine load with electric brake.

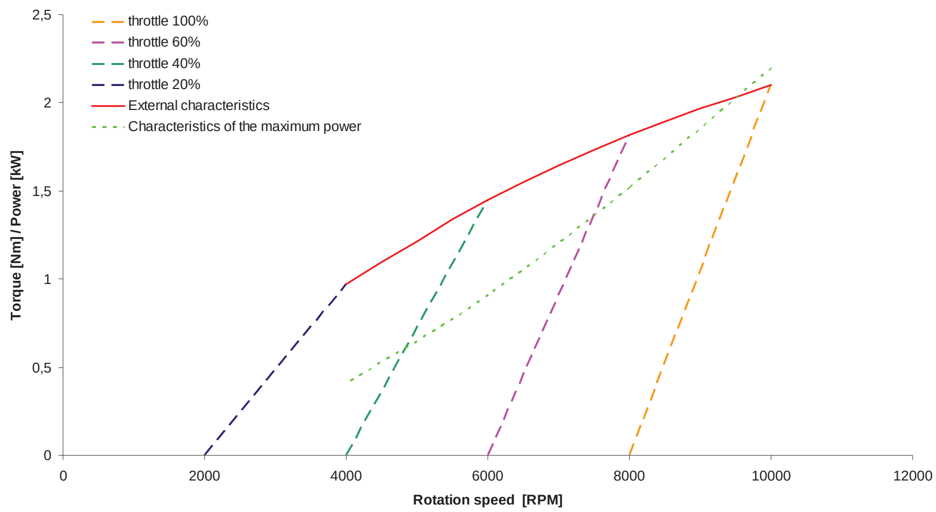

Fig. 4. Family characteristics of internal combustion engine torque versus engine speed for different angles of the throttle opening and the maximum torque curve - electric brake

The disadvantage of burdening low-power engine with electric brake is a step change of load. Grabbing the engine load changes due to the fact the electrical load (power output) by the need for further integration of power receivers (light bulbs).

The diagram of the load using a low power engine propeller aircraft with a power receiver shown in Fig. 5.

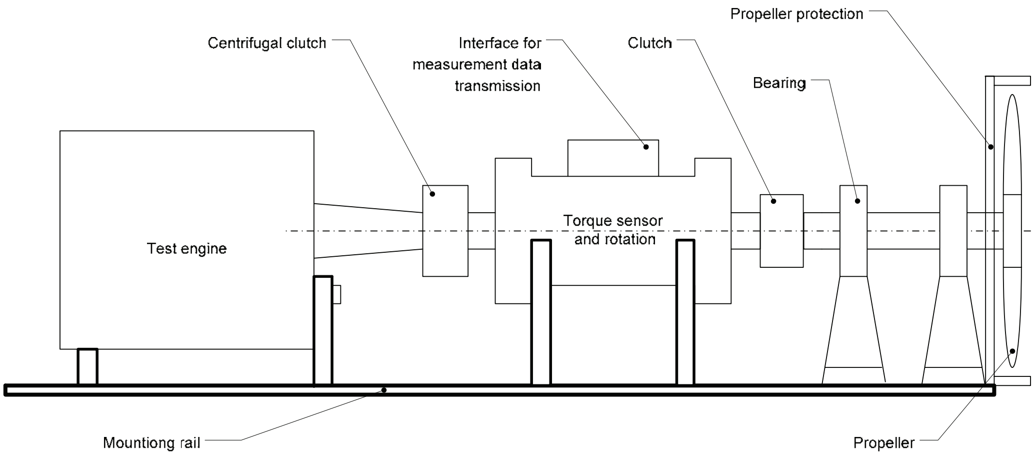

Fig. 5. Diagram of small power engine test bench, using air as the propeller power receiver

Up and reaches the maximum speed by the combustion engine for the opening of the throttle is a gradual debiting through the propeller of his air of constant angle of attack. After stabilizing the engine speed is measured until the loading and calculating the motor torque based on data from the sensor point and tachometer (counter rotation). The result is a family of characteristics of the engine torque as a function of engine speed for various throttle angles at a constant angle of attack aircraft propeller (incriminating). Maximum torque characteristics of internal combustion engine with its load of air propeller fixed angle of attack plotted by connecting the tops of the family characteristics of the torque curves of the internal combustion engine as a function of engine speed for different angles of the throttle opening. Charging the internal combustion engine blades at different angles of attack, allows you to specify the characteristics of the family until the maximum for each angle of attack of air propellers.

Figure 6 shows the family characteristics of the engine torque as a function of engine speed for different angles and throttle curves for propellers of maximum torque at different angles of attack. The curves shown in Fig. 6 were plotted on the basis of experimental internal combustion piston engine type of low power OS Max 50 Heli SXH the view that uses the engine load the package of air propellers with different angles of attack.

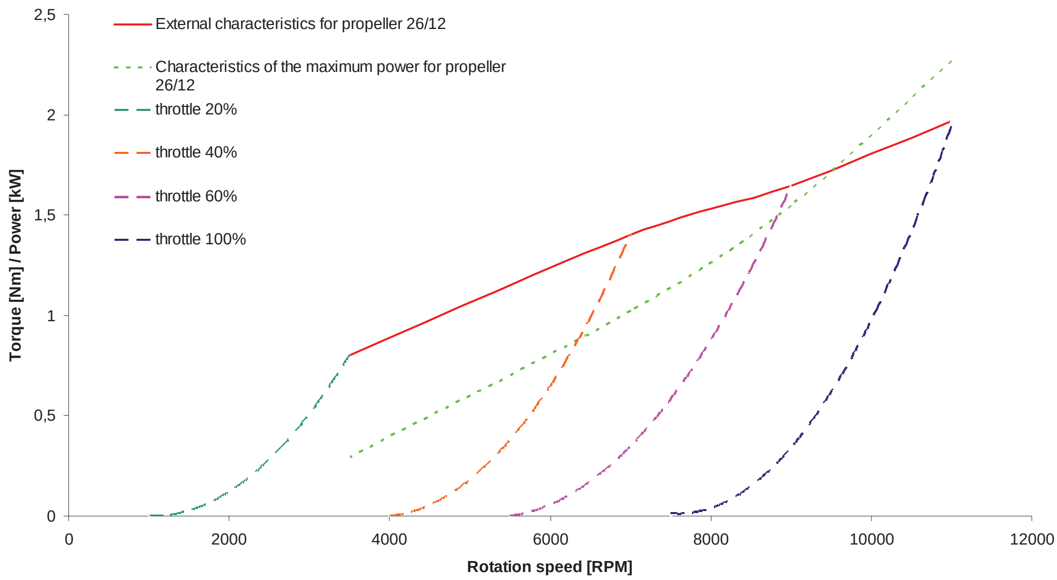

Fig. 6. Family characteristics of internal combustion engine torque versus engine speed for different angles of the throttle opening and the maximum torque curve for air propellers 26.12

The disadvantage of burdening low-power engine with a propeller aircraft is the difficulty in obtaining the maximum power the engine. The difficulty in obtaining the maximum engine power due to the facts that the change in propeller drag is associated with rotation of the propeller. This results in a smooth movement of a stable operating point of the internal combustion engine to the point of balancing the speed of the wind resistance of the propeller. Balance Point propeller aerodynamic drag and torque delivered by the internal combustion engine is not the maximum engine torque.

Figure 7 to 9 have been characterized from the experimental internal combustion piston engine type of low power OS Max 50 Heli SXH the view that uses the engine load by means of a hydraulic brake. Fig. 7 shows the characteristics of the maximum engine power at zero throttle the engine (idling), the Fig. 8 at 50% throttle the engine, and the Fig. 9 at full throttle the engine. Due to the significant effects on measured values of changes in atmospheric pressure, humidity and temperature measurement results of power and engine torque has been normalized. The resulting measured values were converted to corrected values of parameters of normal (DIN 70020).

4. Summary

The proposed method for determining the power and torque engine power into a small VTOL UAVs or UAVs rely on a balance of forces driving the internal combustion engine with hydraulic brake, electrical and propeller and engine power calculation based on data from the strain gauge (force sensor) and a tachometer (counter rotation). Measurement time is defined as the full load at constant speed (engine it will continue the stable operation point) for each measuring point (specifically selected throttle opening angle).

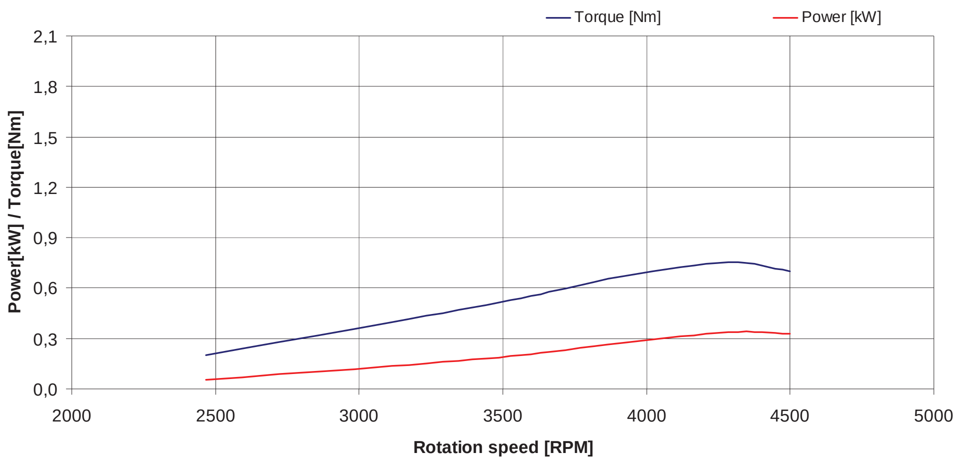

Fig. 7. Characteristics of maximum engine power at zero throttle the engine (idling) when the engine brake hydraulic load

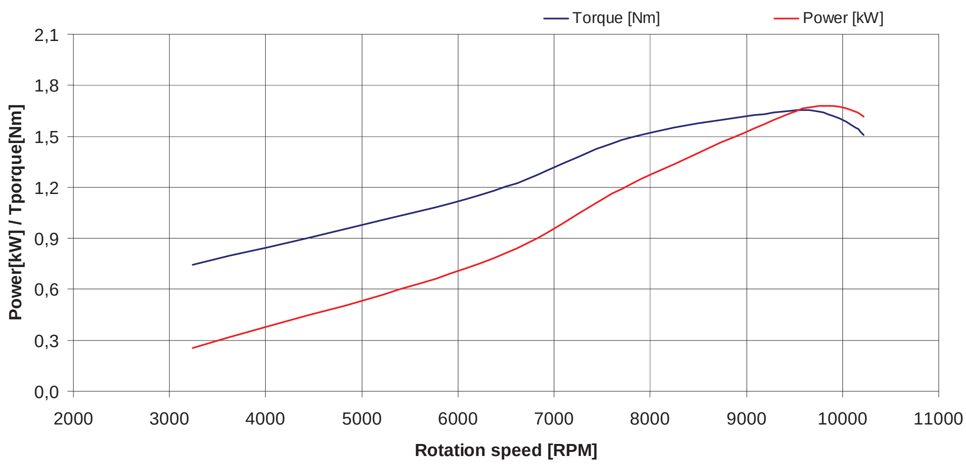

Fig. 8. Characteristics of maximum engine power at 50% throttle engine brake hydraulic engine load

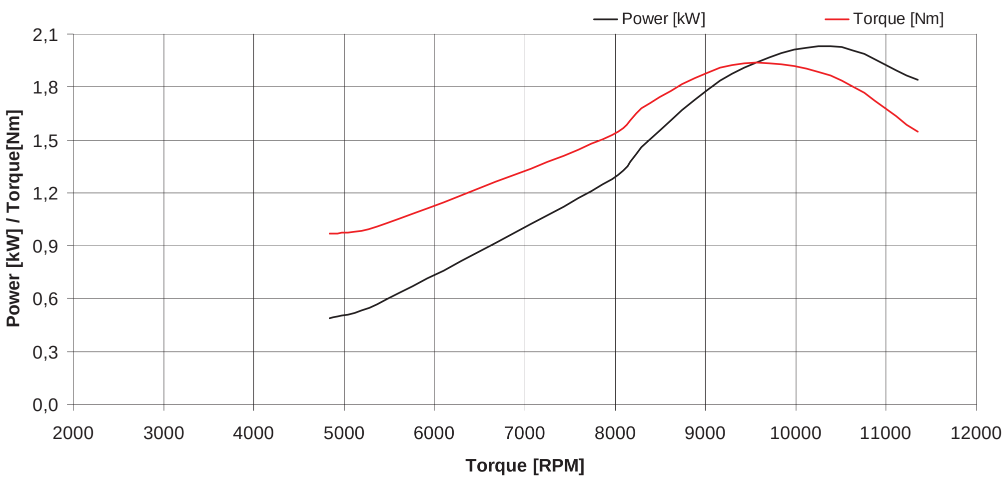

Fig. 9. Characteristics of maximum engine power at full throttle engine brake hydraulic engine load

The measurement of motor torque on the rig with hydraulic brakes (with load balancing in the motive power mode) allows you to keep the engine at a speed of interest (liquidity of the engine load changes), but it is difficult to achieve stable operation of the engine for maximum power at the throttle. The method of charging a piston engine with hydraulic brake can be applied to a strenuous test.

The measurement of motor torque on the rig with an electric brake (with load balancing in the motive power mode) can achieve stable operation of the engine at maximum power for a throttle. Received from the engine torque is due to its speed, increasing the electrical resistance of the power load increases and a drop in engine speed of the engine.

The measurement of motor torque as a propeller brake (with load balancing in the motive power mode) can achieve stable operation of the engine with the throttle. Obtained in measuring the balance point of aerodynamic drag and the propeller torque delivered by the internal combustion engine is not the maximum engine torque and thus the calculated engine power will not be his maximum power.

The preferred method for determining the power and torque characteristics of internal combustion engines used in UAVs and UAV VTOL is the study of the position of the load by using a family of air propellers. This method allows the explicit representation of the real pressure on the VTOL UAV or UAV.

When calculating the maximum engine power to account for changes in atmospheric pressure, humidity and air temperature. These factors affect the measured values of engine parameters. Measuring the results obtained should be converted into value-adjusted normal parameters {acc. DIN 70020 - 25 degrees C and 1000 hPa (not including humidity) and a special adjustment factor - an estimated output changes by 1% when changing the}