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MEASUREMENT OF PHYSICAL PERFORMANCE USING DYNAMIC METHODS

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Abstract – The utilization of dynamic methods for the measurement of operating parameters of road vehicles is beginning to grow due to small time-consuming and low initial investment funds. Dynamic measurement of power parameters of the engine or brake are generally based on the knowledge of the moment of inertia of the rotating masses both of engine and transmission system including driving wheels. Based on the same assumption, dynamic measurement methods can be used to determination of athlete's physical performance. The results may serve primarily in the sports training area to determine the readiness of the athletes. Secondarily, results may serve as feedback data for optimal couching and they can help to increase of athlete's technique. This paper deals with dynamic measurement methodology and with measurements results obtained on group of 85 students.

Keywords: dynamic methods, power, torque, physical performance

1. INTRODUCTION

Large-scale development of dynamics measurements methods used on vehicles and their engines gives a new opportunities on the field of diagnostics. One of possible kinds of dynamic measurements is measurement of power and torque of the engine [4.]. Measurement can be accomplished in the following ways: at engine itself, by using of rolling road or directly on the test track [3]. In all these cases there is necessary to calculate using of right values of moment of inertia of the engine or whole car body. When the measurement is carried out at the engine itself, the influence of moment of inertia is crucial [6].

It is possible to use similar methodology as mentioned above to make physical performance tests of the individuals, especially of the athletes. Obtained instantaneous power is linked with explosive strength of tested person and their endurance performance is in order of magnitude lower, i.e. test itself cannot give endurance linked results [5]. In most sporting disciplines is a dynamic force more important than the static force [8]. It is necessary to develop the dynamic force using of properly chosen training plans. Also is necessary to periodically check if the training method give expected results [7].

Especially in case of young athletes or in case of people who choose between several disciplines there is possible to utilize of dynamic measurement methods aimed at power parameters. This article deals both with principles of dynamic measurements and evaluation of obtained data. Based on data analysis there is possible to evaluate dispositions of individual's and this way help to his decision.

In the evaluation of sports performance is continually meet with unauthorized sport enhancing, such as doping. Later described measurement method can be fooled like in case other sport disciplines. To avoid a doping was limited to a minimum, there is regular and random doping control [1][2].

In case of measurements described in this article, there is evaluation of collection of 85 students between 4th and 5th year of study at the Czech University of Live Sciences Prague. All of students were from 20 to 25 years old, while this group also contained active athletes.

2. MATERIAL AND METHODS

In the department of authors was designed and manufactured so called "Instantaneous power test device" (Fig. 1). This measuring device consist mainly of flywheel, gears, rope pulley and speed sensor. Speed of rotation is measured using incremental encoder (Fig. 2), which gives 1024 impulses per one revolution of coaxially attached flywheel. Moment of inertia of steel disk of the flywheel is 0.09 kg·m^2. The flywheel is spinning up using aluminium alloy pulley equipped with static climbing rope having an outer diameter d = 6 mm. Torque is transmitted through two of chain transmissions. Overall gear ratio between pulley and flywheel is given as i=0.25(-).

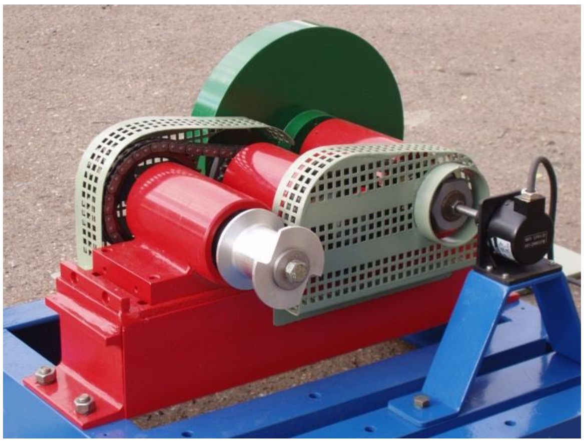

Fig. 1 Instantaneous power test device.

Fig. 2 Incremental encoder.

Measurement is based on dynamics method using (1) and (2). It is assumed that moment of inertia of all rotating parts is known.

$$M = I \cdot \varepsilon \qquad (1)$$

$$P = M \cdot \omega \qquad (2)$$

where:

M is torque (N m),

I is moment of inertia ($kg \cdot m^2$),

ε is angular acceleration ($rad \cdot s^{-2}$),

P is power (W),

ω is angular speed ($rad \cdot s^{-1}$).

Moment of inertia of all rotating parts was measured during spinning up using weight of 5 kg. Resulting overall moment of inertia is given as 0.18 $kg \cdot m^2$.

Measurement procedure consist of pulling of the inflexible rope that had be wound up at the pulley which is attached to the flywheel using transmission. According to evaluated value there is necessary to adapt the way of pulling. If is evaluated the maximum force in the rope, i.e. maximum torque there can be pulled at maximum at any time. However, if it is evaluated power, it is necessary to pull the rope with maximum force at the highest possible speed.

Speed of flywheel is evaluated based on data obtained from incremental encoder, which gives 1024 impulses per one revolution. Data collector unit (Fig. 3) counts incoming impulses and adds timestamp to each value of internal counter. Resolution of internal time base of 20 ns is given by frequency of internal oscillator running at 50 Mhz. However, to the attached personal computer are transmitted only cumulative data of internal counter in certain sampling rate (usually at each 50 up to 200 ms). Example of recorded data is shown in Table 1.

Table 1. Example of recorded data.

Timestamp	Counter
2078821252	21534
2081134459	21535
2083081169	21536
2086513338	21538
2088231259	21539
2092151208	21541
2095501454	21542
2118951323	21543
2134118747	21544
2136661121	21545
2139586812	21547

Fig. 3 Data collector unit.

From recorded data it is sequentially computed rotational speed of flywheel, angular speed, acceleration, torque at the flywheel and power. Speed of flywheel as revolutions per minute is calculated according to formula (3).

$$ns_i = \frac{(imp_{i+1} - imp_{i-1}) \cdot 60}{1024 \cdot (t_{i+1} - t_{i-1}) \cdot 0{,}00000002} \tag{3}$$

where:

ns_i is rotational speed in row *i* (min^{-1}),

$imp_{i+1,\, i-1}$ is impulse counter value in row *i+1*, *i-1*,

$t_{i+1,\, i-1}$ is timestamp in row *i+1*, *i-1* ($\text{s} \cdot 0{,}00000002^{-1}$),

1024 are incremental encoder pulses per one revolution.

The resulting value of rotational speed is calculated as moving average of rows i-1 to i+1. Further, angular velocity is calculated as in (4).

$$\omega s_i = \frac{\pi \cdot ns_i}{30} \tag{4}$$

where:

ωs_i is angular velocity in row *i* ($\text{rad} \cdot \text{s}^{-1}$),

ns_i is rotation speed in row *i* (min^{-1}).

In order to determine the torque and power of individual according to (1) and (2), it is still necessary to calculate the angular acceleration. Calculation (5) is done using moving average as in case of rotation speed.

$$\varepsilon s_i = \frac{(\omega s_{i+1} - \omega s_{i-1})}{(t_{i+1} - t_{i-1}) \cdot 0{,}00000002} \tag{5}$$

where:

εs_i is angular acceleration in row *i* ($\text{rad} \cdot \text{s}^{-2}$),

$\omega s_{i+1,\, i-1}$ is angular velocity in row *i +1*, *i-1* ($\text{rad} \cdot \text{s}^{-1}$),

$t_{i+1,\, i-1}$ is timestamp in row *i+1*, *i-1* ($\text{s} \cdot 0{,}00000002^{-1}$).

Flywheel torque is calculated as in (1). Torque at the pulley is given by overall transmission ratio. Power of athlete is calculated according to (2), where can be used torque at the flywheel or at the pulley.

Effective values of the power parameters (while flywheel is spinning-up) includes also values of losses (while flywheel is decelerating). This way eliminates losses that must be overcome by athlete beyond the moment of inertia. Estimated value of losses is not entirely accurate because of while acceleration and deceleration there are involved opposite sides gear tooth. This difference can be neglected in case of considered application.

3. RESULTS

Example of power parameters data evaluation is shown (Fig. 4). Can be derived several important points including the maximal values. Maximal torque 18.1 N·m has been achieved at 890 rpm while maximum of power 1813 W is placed at 985 rpm.

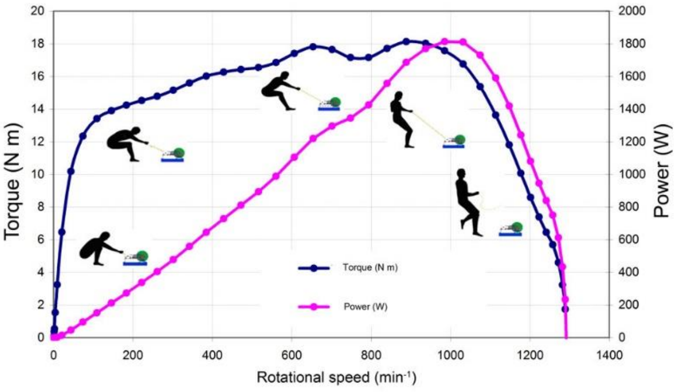

Fig. 4 Example of power parameters data evaluation.

Example (Fig. 5) shows evaluation of sample collection of data. This the case of 85 male students aged from 20 to 25 years. Their average power achieved 1187 W. Maximal obtained value of power achieved up to 2712 W, while minimum of power is 341 W.

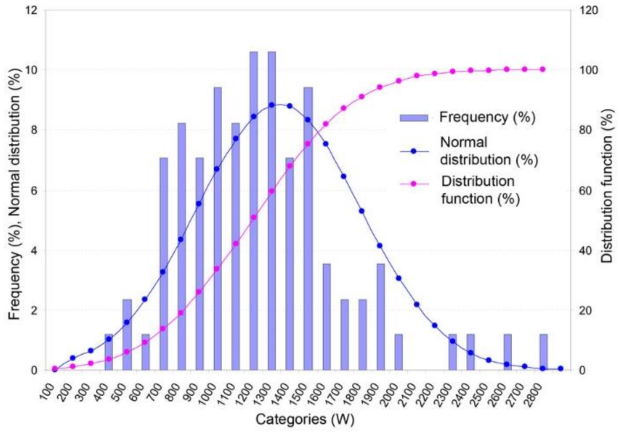

Fig. 1 Distribution of power – students from 20 to 25 years old.

The extra class level, which can be considered power of 2000 W was overcome in case of approx. 3.5% of all students. Value of 1500W was overcome in case approx. 25% of all students. In contrast 10% of students are not able to overcome level of 600 W.

Best power was reached at 20 Nm, which is equivalent to 320 kg weight to lift. Best value of torque of 25 Nm, which is equivalent to 410 kg weight to lift was achieved by another student. To realize maximum power, it is necessary to hold high value of torque up to highest rotation speed. Rotation speed is different both for power and torque record breakers. Best value of power was overcome at rotation speed of 1500 rpm, while best value of power was overcome at rotation speed slightly above of 1400 rpm.

4. CONCLUSIONS

Dynamic measurement methods can be utilized in case of athletes or generally in case of individuals. This paper described example of possibility of performance testing aimed to instantaneous power measurement of individuals. Similarly, evaluation of maximal torque and maximal speed of rotation can be used.

Power parameters on the basis of the important points can be discovered (Fig. 4). This points are related to motor skill i.e. to overall technique of person under test.

Example of measurement is supplemented by 85 student data evaluation. Their average power achieved 1187 W. Maximal obtained value of power achieved up to 2712 W, while minimum of power is 341 W. The extra class level, which can be considered power of 2000 W was overcome in case of approx. 3.5% of all students. Value of 1500 W was overcome in case approx. 25% of all students. In contrast 10% of students are not able to overcome level of 600 W.

Described application of measurement using the dynamic method seem to be suitable for testing in different sport activities and allows to quickly evaluate the overall physical readiness of athletes.

At the same time the suggested method allow the analysis of major power parts individually and their consistency with the overall physical load. There is often required to synchronize the work of the lower limbs, trunk and upper extremities. When using the "Instantaneous power test device" it can be expected increase of performance and achieving better results in sports.

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