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PROBLEMS OF POWER PARAMETERS MEASUREMENT OF CONSTANT-SPEED ENGINES WITH SMALL CYLINDER VOLUME BY ACCELERATION METHOD

The main topic of the paper is determination power parameters of constant-speed engines designed with small volume cylinders. These spark-ignition engines are equipped with simple carburettor with main circuit for full load and in some cases with idle circuit for unloaded modes. The absence of additional acceleration circuits cause considerable decrease of torque in engine's characteristic under low engine speed. It determines the common acceleration method as unsuitable for its utilisation.

***Keywords**: moment of inertia, acceleration, power, torque*

1. Introduction

Problems of power parameter measurement of the internal combustion engine designed with small volume cylinders (e.g. spark-ignition engines of lawn mowers) by the acceleration method can be divided into two parts. The first problem is a determination of the measured engine's inertia moment. The second problem is fast acceleration engines which are designed as the constant-speed engine. Fuel systems (commonly carburettor) of these engines are relatively simple. They are not equipped with the additional circuit for acceleration in comparison with of automobile engines. The absence of additional acceleration circuits in the carburettor causes considerable decrease of the torque in the engine's characteristic under low engine speed. This problem can be eliminated by using the additional moment of inertia that prolongs acceleration. Fig.1 and Fig.2 show the decrease of engine acceleration with and without the additional moment of inertia. Fig.3 shows the final torque and power engine characteristic.

2. Materials and methods

The principle of determination of the internal combustion engine's power parameters by the acceleration method is founded upon measurement of an angular ε [rad·s^{-2}] of a crankshaft, which is directly proportional of a torque M [Nm]. At known moment of inertia I [kg·m^2] of all engine rotating parts, including non-disengageable equipment, we can use a formula, which results from the second Newton's law and it is generally true for solids rotating around fixed axes.

$$M = I \cdot \varepsilon \quad [N \cdot m] \qquad (1)$$

where: M – torque [Nm], I – moment of inertia [kg·m^2], ε – angular acceleration [rad·s^{-2}]

For determination of the moment of inertia of all rotating parts of the engine has been chosen the method based on measurement of the time of vibration of inertia masses on trifilar hangings according to formula:

$$I = \frac{T^2 \cdot m \cdot g \cdot r^2}{4\pi^2 l} \quad [kg.m^2] \qquad (2)$$

where: I - moment of inertia [kg.m^2], T - time of vibration [s], m –mass [kg], r – radius rotation [m], l – lenght of hangings [m], g - acceleration of gravity [m.s^{-2}]

3. Result

3.1 Problems of transient regimes

Fig.1 and Fig.2 show decrease of the engine acceleration with and without the additional moment of inertia.

Both graphs (Fig.1 and Fig.2) clearly reflect on decrease of the engine acceleration without the additional moment of inertia. From running the black line is perceptible that the increasing moment of inertia reduced unfavorable running transient performance.

Fig. 3 shows the final torque and power parameters of the measured engine with the additional moment of inertia. The individual points of line are calculated from formula [1].

3.2 Measurement of the moment of inertia

Individual parts (an engine's flywheel and an engine's crankshaft) representing the major component of the total moment of inertia was dismounted

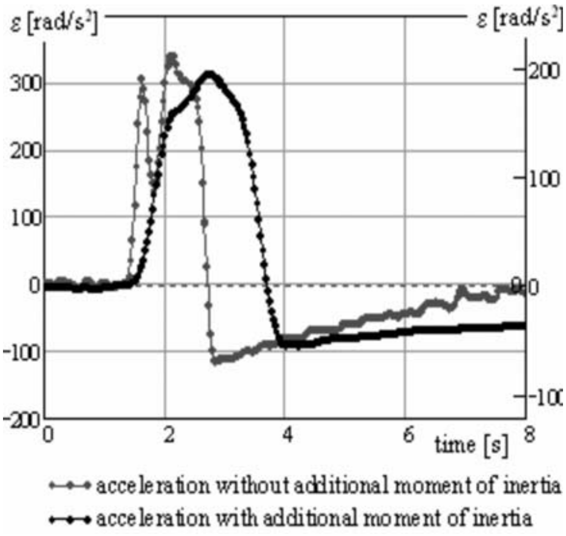

Fig.1 Engine acceleration

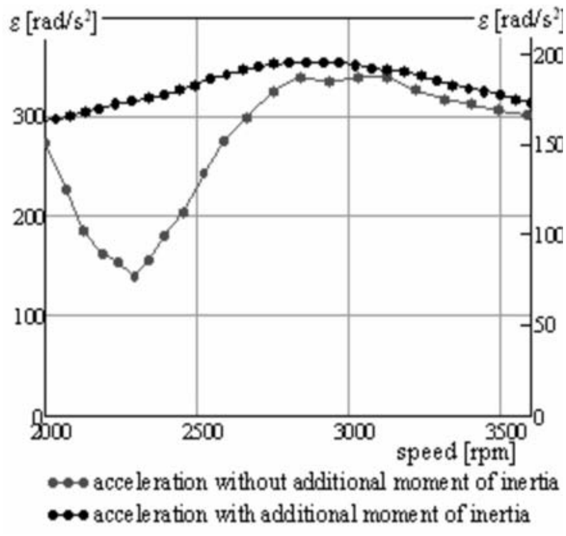

Fig.2 Engine acceleration

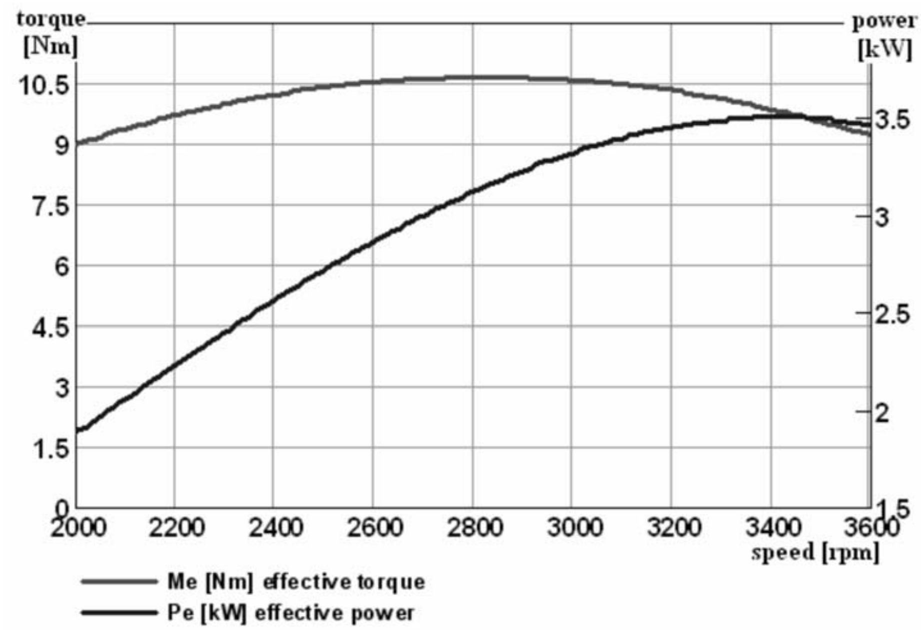

Fig.3 Final graph of the engine's power parameters measured with the additional moment of inertia

out of the engine and fixed to the trifilar hangings (Fig. 4 and 5). The moment of inertia was calculated from the measured time of one vibration according to formula (2).

4. Discussion

The method of measurement of free acceleration of an unloaded engine has been known since beginning of the maintenance practice. For relatively long time, when the objective engine dynamometer has already existed, it was the only subjective method, based on experience of mechanics. Development of electrical technology brings using of a simple analogue apparatus with relatively low accuracy. Relatively recently within the context of fast development of digital electronics and computer techniques, which are capable to monitor and evaluate even very fast dynamic actions, it is possible to talk about seriousness of this method. Unfortunately laity but in some cases even specialist public still consider this method to be only orientational measurement of engine's parameters.

In view of physical and metrological standpoint this method is highly accurate and excellently repeatable; because it's the only method unaffecting metering results with inherent waste and hysteressis, unlike for example a dynamometer. Accuracy of measurement of the angular acceleration that is principle of the method is dependent explicitly on accuracy of metering time

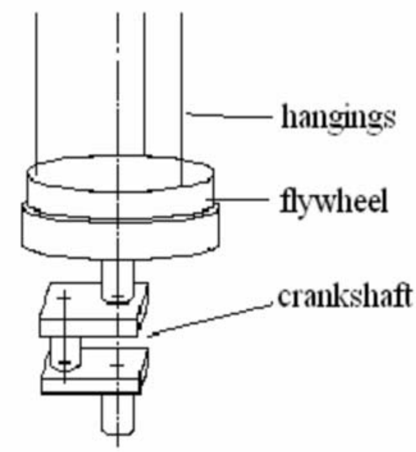

Fig.4 Diagram of measurement moment of inertia

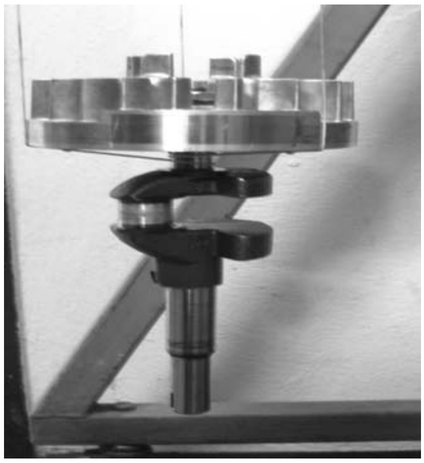

Fig.5 Measurement of moment of inertia flywheel with crankshaft

Tab.1 Measurement of time of one vibration

Measurement of time of ten vibration [s]	Engine's flyweel	Engine's flyweel with engene's crankshaft	Adittional moment of inertia
measurement č.1	19.40	16.20	22.40
č.2	19.25	16.21	22.35
č.3	19.31	16.09	22.51
č.4	19.32	16.35	22.32
č.5	19.47	16.31	22.39
č.6	19.16	16.28	22.48
č.7	19.25	16.22	22.58
č.8	19.35	16.35	22.39
č.9	19.42	16.08	22.43
č.10	19.26	16.24	22.36
average time [s]	19.319	16.23	22.421
time of one vibration [s]	1.9319	1.623	22.42

Tab. 2 Result of moment of inertia

	Engine's flyweel	Engine's flyweel with engene's crankshaft	Adittional moment of inertia
m mass [kg]	2.536	4.262	8.369
r radius rotation [m]	0.0825	0.0825	0.0825
l lenght of hangings [m]	1.638	1.638	1.638
Moment of inertia [kg.m^2]	0.0113	0.0116	0.0434

or more precisely on the time in which the crankshaft turns by the constant angle. Multiyear practical results reflect that measurement of time with accuracy approximately ± 5 [μ s] is sufficient for metering of power parameters of the whole engine.

Slightly other is the situation in determination of the value of moment of inertia of all rotating engine parts reduced on crankshaft. The significant argument of critics of this method is just determination of the value of moment of inertia and thus the easy possibility of non-serious influence on results metering. Because the value of moment of inertia is a constant, an appropriate mistake in its determination is significant, but only systematic; it is not a random mistake of measurement.

Problems of stabilization of air fulfilling parameters and corresponding fuel quantity in dynamic regime are other discussed problems of metering of power parameters by the acceleration method. For completeness it is necessary to solve this problem in turbocharged engines and in the most modern engines with a variable engine intake. But it is not an unsolvable problem. Except for this represented solution (increase of moment of inertia that prolongs accelerations) it is possible to use an alternative method of dynamic metering. For example the method of quasi-static metering that consists in stabilization of a loaded and speed engine closely before acceleration metering. Unlike the classic free acceleration this method doesn't start with fast moving of the acceleration pedal. Measurement of power parameters by the acceleration method in the quasi-static method comes after releasing the engine from load with the constant position of a throttle valve. This manner of metering enables stabilization the engine's input parameters before acceleration metering and in addition to that in constant regimes it is possible to meter the engine's output parameters e.g. emission and fuel consumption.

5. Conclusion

The additional moment of inertia that prolonged acceleration eliminated the considerable decrease of the torque in the engine's characteristic under the low engine speed. The additional moment of inertia did not influence the advantage of the power parameters measurement by the acceleration method.

As it was remarked above it is evident that measurement of power parameters by the acceleration method has several significant problems, which are inhibiting its expansion in maintenance practice. On the other side the method of free acceleration has many significant advantages. Other significant advantage, which results from principle metering, is unlimited range of measuring power parameters.

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