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THE COMPARISON OF POWER, ECONOMY AND ECOLOGICAL PARAMETERS OF SPARK-IGNITION ENGINE OF LAWN MOWERS

The subject of this report is a description of measuring results and mutual comparison of power, economy and ecological parameters of spark-ignition engines. Four engines equipped with a vertical crank-shaft with power from 3 to 5 kW were compared. These engines were mounted as a drive unit on lawn mowers.

Keywords*: engine, mower, power, torque, specific fuel consumption, emission, vibration*

Introduction

Small lawn mowers and other small mechanization, as chain-saws, brush-saws, tillers etc., driven by a combustion engines meet, from the point of view of economy and ecology, with similar problems of operation as are solved traditionally and in long-term with engine-driven vehicles and self-propelled agricultural machines. Combustion engines of small mechanization perform substantially smaller problem from the point of view of the harmfulness and of the impact on sustainable environment. On the other hand operators of the machines are immediately exposed mainly to a harmful emission impact and vibrations. That is why it is necessary to pay an adequate attention to problems of economical and ecological parameters as during a machine selection as during a machine maintenance.

For this particular purpose special measuring equipments i.e. power (efficiency) dynamometers and cooperating emission analyzers are not readily available in the market. That is why authors used under mentioned non-traditional measuring procedure based on dynamical efficiency measurement and so-called quasi-static measurement of emission parameters, fuel consumption and vibrations.

1. Brief description of the experimental measurement

The measurements were done at the emission control station and in laboratories of Department of Vehicles and Land Transport of Technical Faculty, Czech university of agriculture in Prague. These types of spark-ignition four-stroke engines with a vertical crank-shaft (Kawasaki engine, „Noname" - made in China, Briggs&Stratton-Intek engine and B&S-Quantum) were measured. The aim of measurement was to obtain a data and according to obtained data values to select the most suitable engine drive of a lawn mower. Data were compared from the point of efficiency parameters, emission impact on the environment, fuel consumption, noise and vibrations.

- The measurement of external revolution characteristics (i.e. torque [Nm] and power [kW] depending on engine revolutions [min^{-1}]). Measurement was carried out by a dynamic method on the base of free acceleration. Torque [Nm] is directly proportional to an angular acceleration [$rad.s^{-2}$] which was measured as well. Moments of inertia [$kg.m^2$] (of every moving mass) must be taken as a constant. The moment of inertia was determined by method of three-rope clamp measurement. Moments of inertia were determined independently for every flyweel of the engines, including a crank-shaft, carrier and chopper.
- The measurement of emission impact on environment (i.e. emission production CO_2 [%], CO [%], HC[ppm]) was carried out by NDIR analyzer (Non Dispersive Infra-Red absorption) under conditions:
  a) Standstill run-idle revolution mode of engine;
  b) Maximal operational revolutions and standstill run on-load mode of engines.
- The measurement of fuel consumption [$g.hod^{-1}$] was carried out under the same engine conditions see a), b). Mass rate of flow meter was used.
- The measurement of exhaust gas temperature, a heat sink (surface) of working engine cylinder temperature and spark plug temperature under the same engine conditions see a), b). This measurement was carried out with a contact thermometer TERMO-PEN (SKF)
- The measurement of vibrations (range of oscillation) [$mm.s^{-1}$] was carried out under the same engine conditions see a), b). This measurement was carried out with a contact vibration meter VIB-PEN (SKF).

All these four cases of measured combustion engines are the question of carburetor spark–ignition engines with a power regulator. It keeps revolutions in dependence on the engine load within the range of 2800-3000 [min^{-1}] according to type. These engines are possible to class as stationary spark-ignition piston combustion engines with single-chamber monocyclic (circuit) carburetor.

Carburetors of the compared engines consist of a main circuit only. It prepares fuel mixture (fuel with an air) mainly for high revolutions and full run load. The carburetor is without some special mechanism for run-idle engine mode and transition dynamic modes. These (above mentioned) technical and design parameters of measured engines did not enable to use a classical method –called the free acceleration which is usually used for e.g. car combustion engines.

2. Theoretical solution of the algorithm for measuring power parameters

The principle of establishing power parameter through the acceleration method is based on measuring angular acceleration ε [$rad\cdot s^{-2}$] of the crankshaft. This is directly proportional to the torque M [N.m]. When the moment of inertia I [$kg.m^2$] of all the mass which rotates with the crankshaft is known than the relation originated from Newton's second law is valid for bodies rotating around an invariable axis.

$$M = I \cdot \varepsilon \quad [N.m] \tag{1}$$

$$P = M \cdot \omega = I \cdot \varepsilon \cdot \omega \quad [W] \tag{2}$$

where: M – Torque [Nm] (effective value), I– moment of inertia [$kg\cdot m^2$], ε – angular acceleration [$rad\cdot s^{-2}$], ω – angular speed [$rad\cdot s^{-1}$].

The measuring method is based on the time of one crank revolution (t_k-t_{k-1} for $\varphi_\kappa = 2\pi$) - the time range between the impulses of flywheel marker.

Averaged angular speed at the time t_k is based on two revolutions:

$$\omega_k = \frac{4\pi}{t_{k+1} - t_{k=1}} \quad [rad\cdot s^{-1}] \tag{3}$$

Angular acceleration of the engine crankshaft ε_k is evaluated as well as a mean value during two revolutions of crank:

3. The most important results of measurement

The over average effective power (see fig.1) and effective torque (see fig.2) were found out at Briggs & Stratton – Intek (190 cm^3) engine.

Effective power and torque parameters of the engine made in China (190 cm^3) and B&S–Quantum (190 cm^3) are comparable.

Lower power and torque parameters were found out at Kawasaki (179 cm^3) engines, that are respond to lower stroke volume.

The comparison of loss torques (fig.3) needed for the getting over of self passive resistance of engines is interesting. In comparison with theoretical presumptions engine Briggs & Stratton Intek had unusual low losses. Loss torque of the B&S-Intek engine is even lower then the Kawasaki engine which is equipped with the lowest stroke volume in comparison with the other engines.

Indicated power parameters are summary indicator of engine efficiency. It is evident (see fig.4) that entirely uncontested position in the area of power parameter among all compared engines has Briggs & Stratton–Intek engine. Other engines are approximately on the same level. Kawasaki engine has slightly lesser parameters that are caused by its smaller stroke volume.

B&S Quantum engine fulfill emission limits (see fig. 5) for non-driven carburetor engines under run-idle engine only. B&S Intek engine has slightly increased emission CO and weak mixture. Kawasaki engine is very weak and with too high emission CO. China engine has the worst total volume of directly harmful emission CO a HC with relatively low production CO_2 and too rich mixture.

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Under the load-run engine mode (adjustment handler on MAX) with app. 3000 revolutions both B&S engines (in order Quantum, Intek) have accep-

$$\varepsilon_k = \frac{2}{t_{k+1} - t_{k-1}}\left(\frac{2\pi}{t_{k+1} - t_k} - \frac{2\pi}{t_k - t_{k-1}}\right) = \omega_k\left(\frac{1}{t_{k+1} - t_k} - \frac{1}{t_k - t_{k-1}}\right) \quad [rad\cdot s^{-2}] \tag{4}$$

where: t_k - a point on the time axis [s], for $k \in \{1,2, ...,k,....\}$, i.e., the instant of pulses from the engine speed sensor, ε_k - angular acceleration [$rad.s^{-2}$] of engine crankshaft close to the k-th time instant, ω_k - angular speed [$rad\cdot s^{-1}$] of the engine crankshaft, close to the k-th time instant (see (3)).

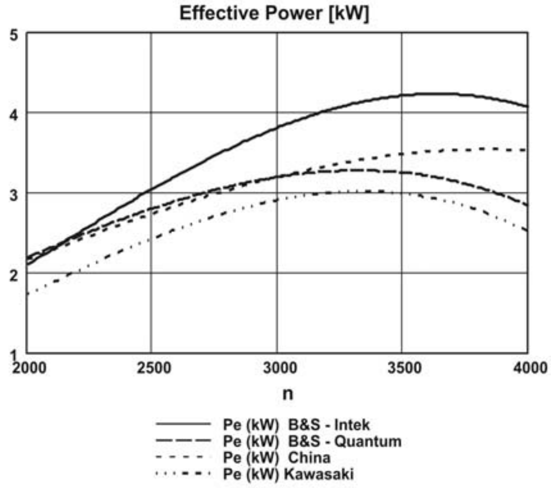

Fig. 1. Comparison of effective power

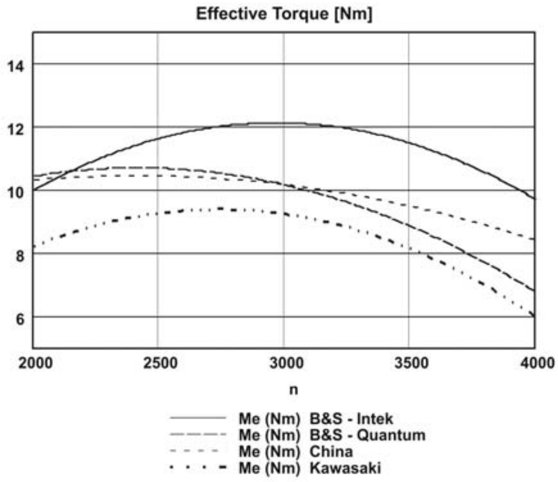

Fig. 2. Comparison of effective torque

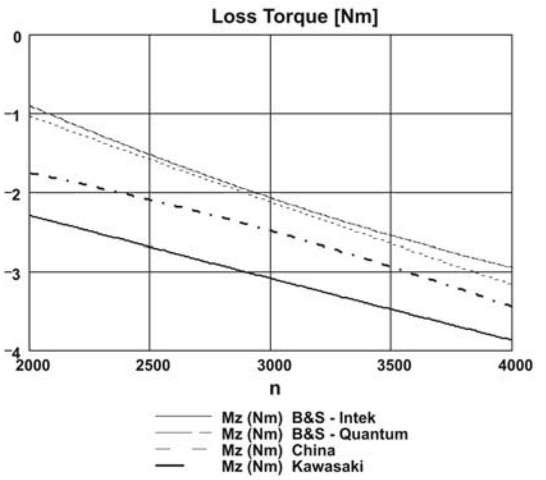

Fig. 3. Comparison of Loss Torques

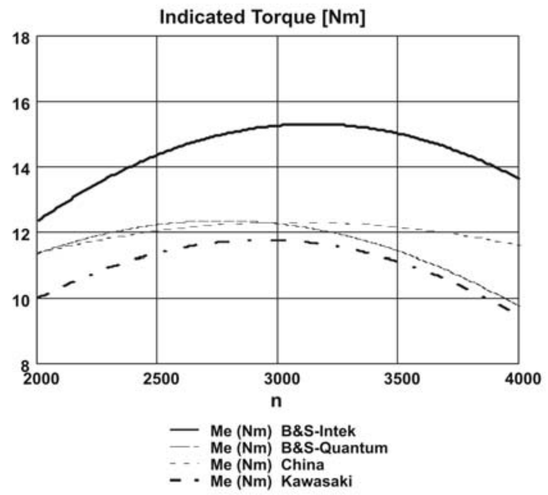

Fig. 4. Comparison of Indicated Torques

table emissions (see fig. 6) nevertheless with slightly increased emissions CO. Next is Kawasaki engine with too weak mixture (more than 4% of residual O_2). Made in China engine is the worst in all emission parameters. (more than 6% CO and hardly zero residua O_2) These parameters of China engine prove too rich mixture that was made with aim of achieve the surplus of power parameters (see fig. 1). These power parameters nevertheless cause the important decline of quality in emission proportionality.

Chart (see fig. 7) proves that the least economical engine is the China under both modes. Under load-run engine mode B&S – Intek engine is evidently the best in relation to the highest powers.

Temperature of exhaust gases increase with a load at all engine (see fig. 8); most notably it is seen at China engine. Spark-plug temperature is balanced at all measured engines with slight increase responding the load.

The accuracy of cutter carrier bearing affects vibrations of a whole mower. The chopper existence damped vibration in some cases but it increased in some cases on contrary. This effect was not searched from the point of quality of carriers. The evaluation of single engine is meaningless from the point of vibrations. It is possible to say in summary that vibration values (range of oscillation [$mm \cdot s^{-1}$]) are quite high at all searched types (see fig. 9). The

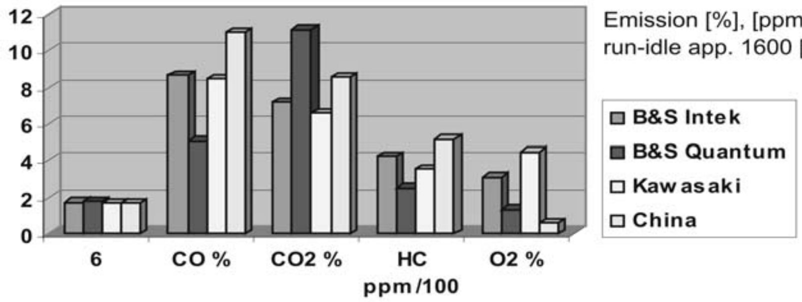

Fig. 5. Summary emission chart under run-idle engine mode app 1600 revolutions per minute (Adjustment handler in position „MIN“.)

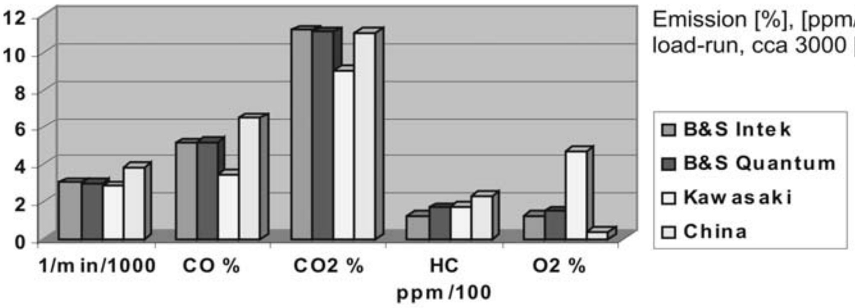

Fig. 6. Summary emission chart under run-load engine mode app. 3000 revolutions per minute (Adjustment handler in position „MAX“)

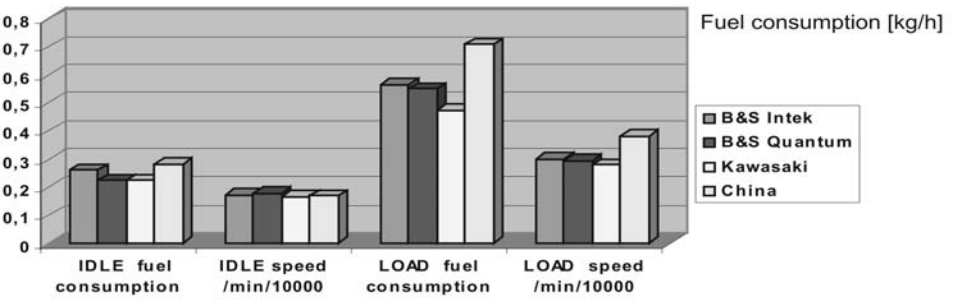

Fig.7. Summary fuel consumption chart [kg/hod.]. On the left - under idle-run engine mode (adjustment MIN), app. 1600 [min^{-1}]. On the right - under load-run engine mode (adjustment MAX) app. 3000 [min^{-1}]

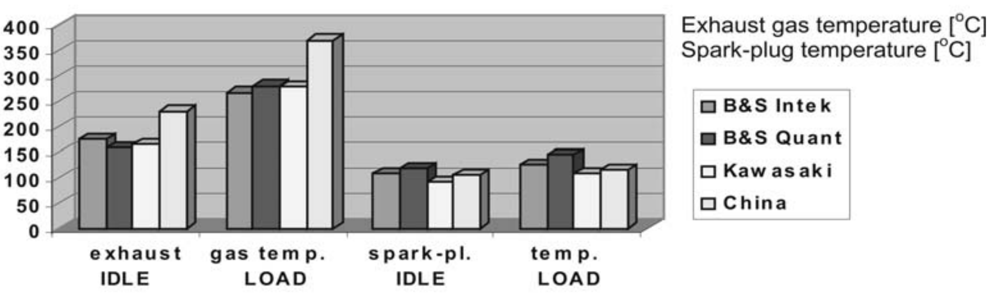

Fig. 8. Summary exhaust gas and spark-plug temperatures chart [°C] under idle-run engine mode, app. 1600 [min^{-1}] and under load-run engine mode, app. 3000 [min^{-1}]

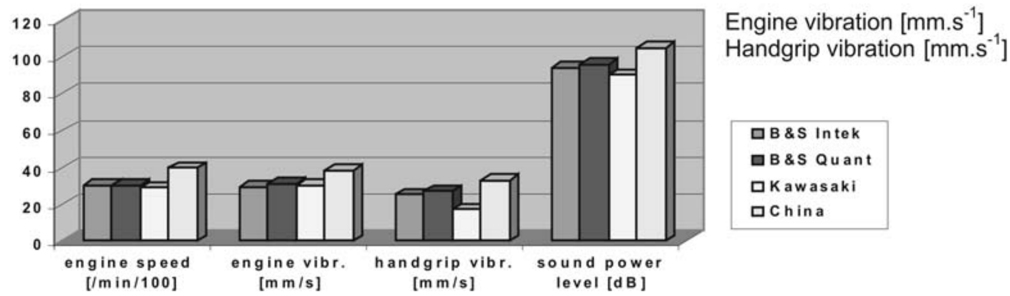

Fig. 9 Summary vibration chart (range of oscillation) [mm.s^{-1}] under load-run engine mode, app. 3000 [min-1]

measured values of noise are high as well namely China engine with more 100 dB.

4. Final conclusion

On the base of above mentioned measurements and analyses, authors evaluate measured engines from the point of power parameters, emission production, fuel consumption and vibration in this order:

Parameters	B&S Intek	B&S Quantum	Kawasaki	China
Power	1	3	4	2
Emission	2	1	3	4
Fuel consumption	1	2	3	4
Vibration&noise	3	2	1	4
Total	7	9	11	14
Classification	first-rate	very good	good low power	the worst cheap

5. References

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