

Določitev imenske moči motorja s poskusom pospeševanja vozila

Determining an Engine's WOT Performance from a Vehicle Speed-Up Test

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V prispevku so prikazani rezultati novo razvite metode, potrebnih naprav in postopka za določitev imenske moči motorja s preskušanjem pospeševanja vozila. Preverjanje karakteristike motorja navadno zahteva demontiranje pogonskega motorja iz vozila pred meritvijo na preskusni zavori, ali pa je treba med motor in preostali del pogonskega sistema vozila vgraditi ustrezen dajalnik vrtilnega momenta. V prispevku predstavljena metoda je preprosta in zanesljiva. Vgraditev merilnih naprav je zelo preprosta, za uspešno meritve pa ni treba odstraniti nobenega sestavnega dela vozila. Metoda omogoča, da izmerimo imensko moč motorja s tremi preskusi: ene meritve pri zaviranju in dveh meritev pospeševanja vozila. Pri tem potrebujemo za izračun moči motorja le omejeno število vhodnih - izmerjenih podatkov.

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(Ključne besede: motorji avtomobilski, karakteristike motorjev, modeli matematični, meritve)

We present a newly developed method, devices and a procedure for determining an engine's wide-open throttle (WOT) performance from a vehicle speed-up test. The control of an engine's performance often requires that the engine is dismantled from the vehicle in order to be able to conduct engine braking test on a bench, or it is necessary to build a torque meter into the drive train of the vehicle. The presented method is very simple and reliable. The mounting of the devices is also very simple, with no need to dismantle any part from the vehicle. The method enables us to derive the WOT performance from three probes, one vehicle deceleration test and two vehicle acceleration tests. The collected test data are processed together with only limited vehicle input data to derive accurate engine-performance figures.

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(Keywords: automotive engines, engine performance, mathematical models, measurements)

0 UVOD

Meritve moči motorja navadno opravimo z meritvami na preskuševališču z uporabo ustreznih preskusnih zavor. Motor je treba pred meritvijo odstraniti iz vozila in ga šele potem pritrditi na merilno zavoro. Omenjeni postopek nas omejuje pri izvajanju meritev na motorju v pogostejših oziroma zaradi vzdrževanja zaželenih in predpisanih časovnih korakih. Poznavanje trenutne moči motorja lahko izdatno pomaga pri ugotavljanju stanja motorja.

Poleg meritev moči motorja na zavori je mogoče moment motorja ugotoviti tudi z uporabo merilnika momenta v pogonskem sklopu vozila.

Ne nazadnje določamo moč motorja tudi na preskuševališču - zavori za vozila z valji. Tam seveda lahko izmerimo moč na kolesih vozila. Pri tem postopku se vozilo ne premika, kolesa pa poganjajo valje merilne naprave. Z izmerjenim navorom pri zaviranju in hitrosti vozila lahko izračunamo pogonsko moč vozila. Preskuševališče z valji je po izmerah zelo veliko in zelo drago.

0 INTRODUCTION

The performance of an engine can be measured on an engine test bed using an appropriate engine-braking device. To carry out these measurements it is necessary to dismantle the engine from the vehicle. This puts some limits on the practicality of performing these measurements at regular intervals or during regular servicing periods. A knowledge of the engine's performance could be very useful in evaluating the health of the engine.

Instead of measuring an engine's performance on an engine test bed it is also possible to use a torque meter to determine the engine's torque in the vehicle drive train, however, this procedure necessitates dismantling the drivetrain parts.

There is also the possibility of using a vehicle-brake-test stand with rollers, which is adapted for measuring the driving power on the vehicle's wheels. The vehicle is fixed to the building's structure and vehicle's wheels drive braking rollers. The drive

Omenjenih merilnih naprav ne srečujemo pogosto v manjših ali celo večjih servisnih delavnicah. V prispevku je opisana nova merilna naprava, ki omogoča določitev imenske moči motorja pri polnem plinu (v nadaljevanju PPP - WOT) s testom pospeševanja vozila. Naprava je zelo preprosta tako po zgradbi kakor tudi pri uporabi. Pri meritvah ni treba izgraditi iz vozila niti motorja, niti katerega koli drugega sestavnega dela vozila. S tem ohranimo tudi jamstvo izdelovalca vozila in izključimo možnosti za okvare delov zaradi nestrokovnega posega.

Predstavljena naprava sestoji iz prenosnega osebnega računalnika (laptop, notebook ipd.), naprave z zaznavalom za merjenje vrtilne frekvence koles, električnih kablov in ustreznih računalniških programov. V računalnik je treba poprej vnesti osnovne tehnične podatke o vozilu in prenosu. Poleg tega potrebujemo še vodoraven, vsaj 1 km dolg odsek preskusnega cestišča, ki ni obremenjen s prometom. Preskuse lahko opravimo v lepem, suhem vremenu brez vetra. Preskus sestavljajo tri faze: en del s prostim zaustavljanjem vozila in dveh meritev s prostim pospeševanjem vozila (v drugi in tretji prestavi). Programska oprema omogoča pobiranje in obdelavo zbranih podatkov do končnega poročila. Zbrani podatki ostanejo spravljivi v računalniku za kasnejše primerjave oziroma ponovljene preskuse.

Pri zasnovi metode je bilo predpostavljeno, da doseže pogonski motor med testom pospeševanja vozila navidezno ustaljeno stanje hitreje kakor se spremeni njegova vrtilna frekvenca. Ta predpostavka je upravičena le pri uporabi sesalnih motorjev. Merilna metoda je le delno uporabna za tlačno polnjene motorje zaradi značilnega "časovnega zaostajanja" teh motorjev. Uporabimo jo lahko pogojno tudi za težja gospodarska vozila s tlačno polnjenimi motorji (s turbopolnilnikom na izpušne pline), vendar mora biti preskus pospeševanja znatno daljši, vozilo pa moramo voziti v višjih prestavah.

1 OPIS MATEMATIČNEGA MODELA

Povezavo med hitrostjo vozila in vrtilno frekvenco vozila podaja enačba:

$$v_v = \omega_w R_w = 2\pi R_w n_w \quad (1)$$

Do vrtilne frekvence motorja lahko pridemo prek prestavnega razmerja prenosnika moči in vrtilne frekvence koles:

$$n_{en} = i_{dt} n_w \quad (2)$$

Kadar se motor pospešuje pri določeni vrtilni frekvenci koles vozila, potrebujemo za pospeševanje vozila in za premagovanje uporov (aerodinamičnega, hidrodinamičnega kotalnega in drsnega) ustrezno moč:

$$P_{en}(n_w) \eta_{dt} = P_{acc}(n_w) + P_{fr}(n_w) \quad (3)$$

power is calculated from the braking torque and the vehicle's speed. This type of test stand is usually large and expensive, and these devices are not usually found in small servicing facilities.

This paper presents a new device that can determine the wide-open throttle (WOT) performance of an engine from a vehicle speed-up test. This device is very simple and easy to use and the procedure does not involve the dismantling of the engine or the vehicle's parts. The vehicle's warranty is preserved and there is no intervening in any vital part of the vehicle's engine.

The device consists of a portable computer (laptop, notebook or similar), a sensing device for the wheel's rotation, wiring and software. It is necessary to input basic vehicle data and drive train parameters. It is also necessary to find an approximately horizontal and straight section of road with a length of 1 km or more. These tests should be made when the traffic is light and when the weather is dry and without wind. The measurement procedure consists of three parts: a single vehicle free-decelerating test and two vehicle accelerating tests (in 2nd and 3rd gears). The software collects and processes the sampled data and then produces a final report. Sampled data are saved for later use or further processing.

During the development of the device it was assumed that the engine driving the vehicle during the speed-up test reached the quasi-steady state faster than the engine speed changes. This assumption holds for naturally aspirated engines but is of limited use for turbocharged engines due to turbocharger lag. Nevertheless, the device could be used even for turbocharged engines in long-term vehicle speed-up tests in higher gears and on long straight tracks.

1 MATHEMATICAL MODEL

The relation between the vehicle's speed and the wheel's rotation frequency is:

$$v_v = \omega_w R_w = 2\pi R_w n_w \quad (1)$$

The drive train transmission ratio relates the engine's rotation frequency to the wheel's rotation frequency:

$$n_{en} = i_{dt} n_w \quad (2)$$

When the engine accelerates the vehicle at a given wheel-rotation frequency, the engine's power is needed to accelerate the vehicle and to overcome all friction losses due to the aerodynamic, hydrodynamic, rolling and sliding frictions.

$$P_{en}(n_w) \eta_{dt} = P_{acc}(n_w) + P_{fr}(n_w) \quad (3)$$

Moč za pospeševanje vozila se porablja za premagovanje vozila s potniki oziroma tovorom, za povečanje kinetične energije pri premočrtnem gibanju vozila in tistega dela, ki povečuje kinetično energijo vrtečih se delov prenosnika moči.

The power for the vehicle's acceleration consists of the parts required to increase the translational kinetic energy of the vehicle (with passengers and payload) and the rotational kinetic energy of the drive train.

$$P_{acc}(n_w) = \frac{d\left(\frac{m_v v_v^2}{2}\right)}{dt} + \frac{d\left(\frac{J_{ef} \omega_w^2}{2}\right)}{dt} \quad (4)$$

$$\frac{d\left(\frac{m_v v_v^2}{2}\right)}{dt} = 4m_v R_w^2 \pi^2 n_w \frac{dn_w}{dt} \quad (5)$$

$$\frac{d\left(\frac{J_{ef} \omega_w^2}{2}\right)}{dt} = 4J_{ef} \pi^2 n_w \frac{dn_w}{dt} \quad (6)$$

$$P_{acc}(n_w) = 4\pi^2 n_w (m_v R_w^2 + J_{ef}) \frac{dn_w}{dt} \quad (7)$$

Celotni dejanski masni vztrajnostni moment vrtenja prenosnika moči sestavljajo posamezni vztrajnostni momenti pogonskih koles vozila, vrtečih se delov prenosnika in vrtečih se delov pogonskega motorja z vztrajnikom:

The drivetrain's effective moment of inertia is the sum of the vehicle's wheels' moments, the drive train's parts' moments and the engine with flywheel and coupling, which are all related to the vehicle's wheels:

$$J_{ef} = \sum_i J_{w,i} + \sum_j J_{dt,j} + J_{enc} i_{dt}^2 \quad (8)$$

V večini primerov zgoraj omenjenih treh posameznih masnih vztrajnostnih momentov vnaprej ne poznamo. Ta nepoznani podatek lahko dobimo s pomočjo dveh preskusov pospeševanja vozila v različnih prestavah (v tem primeru v drugi in tretji prestavi).

In most of cases, the moment of inertia of the drivetrain's components, the wheels and the engine are not known. These unknown values are determined by using two acceleration tests in different gears (in this case 2nd and 3rd).

V prikazanem merilnem postopku ni treba analizirati posameznih uporov oziroma izgub in njihovih deležev, ampak le skupno vsoto izgub. Potrebna moč za premagovanje tornih izgub je določena s preskusi ustavljanja (zaviranja) vozila. Vozilo poženemo – v določeni prestavi - do hitrosti, pri kateri dosežemo imensko vrtilno frekvenco motorja. Nato ob sproščeni sklopki pustimo, da se vozilu zaradi tornih izgub zmanjša hitrost. Moč trenja lahko izračunamo z enačbo (3):

In the presented measurement procedure it is not necessary to analyze various parts of friction losses while only the summary losses are accounted for. The power needed to overcome the friction losses was determined from the vehicle's deceleration test. The vehicle is driven to a speed that corresponds to the maximum engine rotation frequency, with regard to the transmission ratio. The coupling is then disengaged and the vehicle decelerates only as a result of frictional forces. The friction power is determined from equation (3) to be:

$$P_{fr}(n_w) = -P_{acc}(n_w) = -4\pi^2 n_w (m_v R_w^2 + J_{ef}) \frac{dn_w}{dt} \quad (9)$$

Iz dosedaj omenjenih enačb lahko povzamemo, da je mogoče določiti moč motorja z uporabo osnovnih podatkov o vozilu in z uporabo časovne spremembe izmerjene vrtilne frekvence koles. Tako izračunamo moč motorja, ki temelji na poznavanju vrtilne frekvence koles vozila, lahko preračunamo na vrtilno frekvenco motorja. Iz te vrednosti moči pa lahko določimo tudi moment motorja. Opisani preračun je tudi jedro opisane metode.

Using this equation we have the possibility to determine the engine's power from given vehicle parameters and by measuring the rate of the wheel's rotation frequency with time. The derived engine power, which is related to the rotation frequency of the vehicle's wheel, is recalculated to the engine's rotation frequency. From the derived engine power, the engine torque is determined. This is the basis of the device's operation.

Iz treh prej omenjenih preskusov lahko določimo naslednje neznanke:

From three tests the following unknowns were determined:

- celotno moč trenja vozila,

- vehicle friction power,

- dejansko moč motorja,
- skupni masni vztrajnostni moment vrtenja pogonskega dela vozila.

Pri tem so bili predpostavljeni, oziroma poznani:

- podatki o motorju in vozilu (skupaj z nosilnostjo – tovorom oziroma težo potnikov),
- prehodni režim delovanja motorja se izvede v zelo kratkem času,
- izkoristek prenosa je poznan,
- med cesto in pogonskimi kolesi ni zdrsa, prav tako tudi ni zdrsa na sklopki motorja,
- preskusna steza – cestišče je vodoravno, v okolici ni vetra.

Meritev časovnega poteka vrtilne frekvence koles vozila je opravljena z meritvami časa, ki je potreben, da se kolo enkrat zavrti. Od časa odvisne podatke shranimo v ustrezno datoteko. Po meritvah so podatki obdelani glede izračuna neznank in za pripravo končnega poročila. V začetni fazi so izmerjeni podatki pregledani, napačni podatki pa izločeni iz nadaljnje obdelave. Izbrani podatki so potem ustrezno zglajeni (da se izognemo kasnejšim posledicam numeričnega šuma pri določanju sprememb vrtilne frekvence) in nato še računalniško obdelani.

Iz časovne vrste podatkov za pretečeni čas enega vrtjaja na merjenem kolesu vozila lahko izračunamo časovni potek prevožene poti vozila v posamezni (od treh) meritvi. Opravljeno pot vozila izračunamo iz enačbe:

$$L_v = 2\pi R_w N_i \quad (10)$$

Vrtilna frekvenca kolesa v poljubnem i -tem vrtljaju je določena z izrazom:

$$n_{w,i} = \frac{1}{\Delta t_i} \quad (11)$$

Časovno spremembo vrtilne frekvence lahko izračunamo iz enačbe:

$$\frac{dn_w}{dt} = \frac{2(n_{w,i+1} - n_{w,i})}{\Delta t_{i+1} + \Delta t_i} \quad (12)$$

2 OPIS MERILNE NAPRAVE

Merilni sistem z vsemi sestavnimi deli je shematično prikazan na sliki 1.

Zaznavalo za merjenje vrtilne frekvence kolesa sestavlja majhen magnet (pritrjen je na notranji rob platišča kolesa). Za merjenje vrtilne frekvence pogonskega dizelskega motorja je uporabljen elektromagnetni rele, ta ga pred mehanskimi poškodbami, ki bi lahko nastale zaradi neustrezne medsebojne lege z vzbujevalnim magnetom, varuje okrov iz plastične mase. Medsebojno lego releja in magneta lahko nastavimo z vmesnikom za prilagoditev, s katerim pritrdimo rele na nosilec blažilnika udarcev (sl. 1).

- engine power,
- sum of the engaged moment of inertia.

The following assumptions were made:

- the engine and vehicle data are known (also the mass of passengers and payload),
- the engine transient is very fast,
- the drive train efficiency is known,
- there is no slip in the engine coupling or between the wheels and the road,
- the road is horizontal and there is no strong influence from the wind.

The wheel's rotation frequency was taken from measurements of the time elapsed for one revolution of the wheel. During the tests, these time-related data were sampled to a data file. After the tests the data were processed to determine the unknowns and the final report was prepared. Data processing of the first sequence data was used to detect and to eliminate false data. The supervised data set is then processed, together with data smoothing to avoid numerical noise amplified by determining the change rate of the rotation frequency.

From the sampled data for the elapsed times for each revolution of the wheel, the time history of the vehicle's travel is determined for one of the vehicle tests. The traveled distance is calculated from the equation:

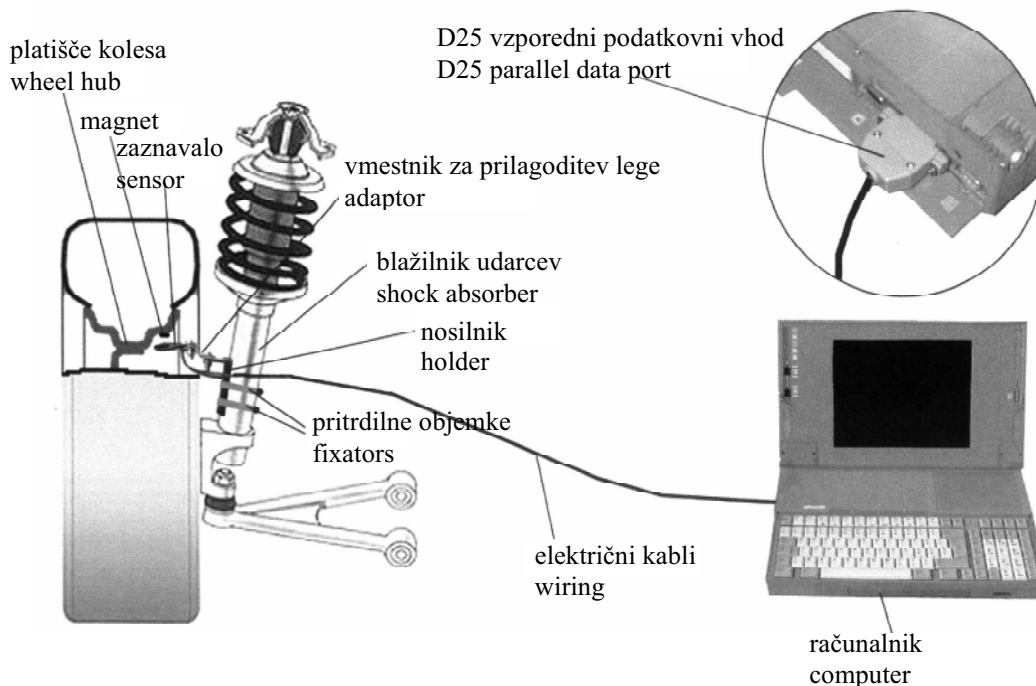
The wheel's rotation frequency for the i -th turn is derived from:

The rate of rotation frequency change is calculated from the equation:

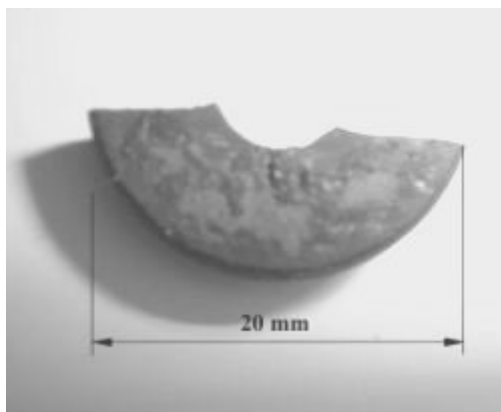
2 MEASURING DEVICES

The complete measuring set-up is presented in Fig. 1.

The revolution sensor consists of a small magnet (cemented to the inner part of the wheel hub) and a small reed-relay (Fig. 2). The reed-relay is from a setup for measuring the revolution frequency of an automotive Diesel engine. A plastic housing protects the reed-relay from any damage caused by a misalignment of the magnet. To keep the reed-relay in the same position with respect to the magnet an adapter for mounting the reed-relay to the shock-absorber leg was used (Fig. 1).



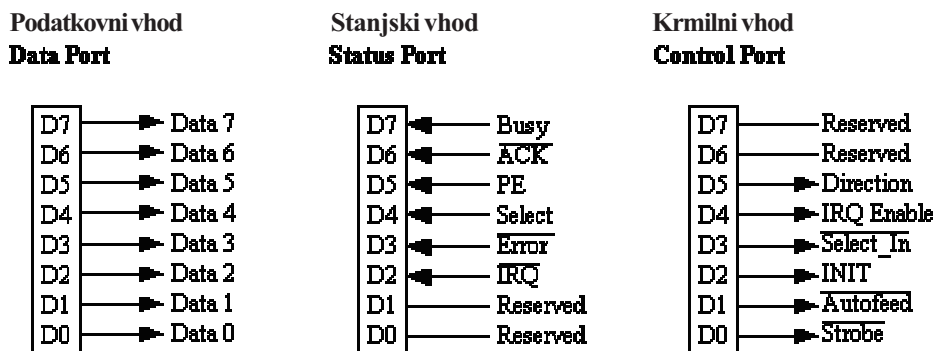
Sl. 1. Shema merilne verige in zbiranja podatkov
 Fig. 1 Measuring set-up for data sampling



Sl. 2. Magnet in rele za merjenje vrtilne frekvence kolesa
 Fig. 2 Magnet and the reed-relay used for sensing the rotation of the wheel

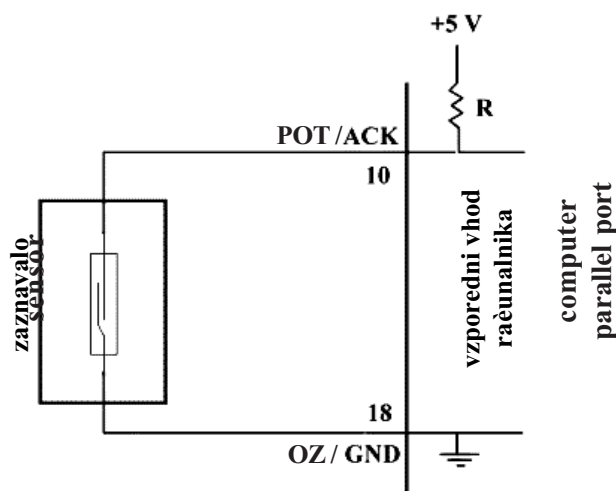
Signal, ki prihaja iz releja, se odvaža prek vodnika do vzporednega vhoda osebnega računalnika. Krmilni del vzporednega vhoda vsebuje povezavo prekinitvene zveze (PZ - IRQ) (sl.3) in omogoča samodejno zaznavanje sprememb vhodnih podatkov. Ta signal sporoča informacijo mikroprocesorju o začasni zaustavitvi delovanja in sproži zeleno funkcijo. Ko je ta funkcija opravljena, procesor nadaljuje svojo prejšnjo dejavnost. Kadar je signal PZ v vklopljeni legi, je prekinitev dokazana vsakič, ko je potrditveni (POT - ACK) vhodni signal na položajnem vhodu preklopljen iz lege "pravilen" v lego "napačen" (ali izklop napetosti). Nastanek in prenos signala k POT vhodu je prikazan na sliki 4.

The signal from the reed-relay switches is fed by wiring to the parallel port of the laptop computer. The control part of the parallel port contains an IRQ Enable connection (Fig. 3) to allow the automatic registration of any change in the input data. This signal is a hardware event giving the information to the microprocessor to interrupt the operation temporary and activate the desired function. When this function is performed, the processor continues with its normal operation. When the IRQ signal is set to the logical "True" (or voltage "ON"), the interrupt is seen each time the ACK input on the status port is switched from logical "True" to logical "False" (or voltage "OFF"). The generation of the signal to the ACK input is shown in Fig. 4.



Sl. 3. Posnetek vzporednih podatkovnih in krmilnih vhodov na merilni napravi

Fig. 3 Parallel ports and port's controls



Sl. 4. Povezava zaznavala z vzporednim vhodom

Fig. 4 Connection of the sensing device to the parallel port

Razvita je bila tudi posebna programska oprema, ki omogoča pobiranje podatkov med meritvijo. Čas med dvema zaporednima zaustavitvama, ki ustreza času enega vrtljaja kolesa vozila se tudi vnaša v podatkovno bazo. Raven natančnosti merjenja tega časa ustreza eni mikrosekundi.

Del programa za zbiranje podatkov je bil uporabljen za kalibracijo merilnika hitrosti vozila. Ustrezni program je omogočil tudi prikaz natančne hitrosti vozila in vrtilne frekvence motorja v vrt/min na zaslonu računalnika. Omenjena podatka sta namenjena za vodenje poteka meritve in preprečevanje morebitne prekoračitve vrtilne frekvence motorja med meritvijo.

Računalniški program za obdelavo izmerjenih podatkov je razdeljen na prvi del, ki preverja in izloča prave in napačne podatke. Napačni podatki nastanejo zaradi neželenega nihanja stikala releja, ali pa merilni podatek včasih tudi izostane. Če je pri meritvi veliko napak, se vsi podatki zavrnejo in meritev je treba ponoviti. Primer vrste popačenih podatkov lahko vidimo na sliki 5.

Preverjeni podatki so potem urejeni, zglajeni in ob koncu prirejeni za končno poročilo o izračunani moči motorja. Program omogoča tudi prikaz vseh podatkov, njihovo obdelavo in prikaz končne oblike

To enable the data sampling during the measurement we developed software. The time elapsed between two successive interrupts, which corresponds to the time of one full revolution of the wheel is written to the data file. The precision of the measurement was at the microsecond level.

One part of the data-sampling software was used to calibrate the vehicle's speed indicator. The software indicates the accurate vehicle speed and engine revolution frequency in rpm on the laptop screen. These data are used to control the test procedure and to avoid engine overspeed during the tests.

The software for sampled-data processing contains the first part for data supervision to detect and to eliminate false data. False data are the result of erroneous reed-relay switch vibrations or due to missing data. If there are a lot of errors, the sampled data are discarded and a new measurement has to be performed. Examples of erroneous data are presented in Fig. 5.

The supervised data set is then processed and smoothed to give a final report on the engine's performance. The software enables sampled-data visualization, processing and presentation of the final

140,203294	73,840134
140,743865	73,852941
141,441164	73,863457
4,010286	148,088236
138,052741	74,081291
142,701352	74,175382
143,513778	74,317489

Sl. 5. Primer vrste napačnih podatkov; levi stolpec – vzrok je v nihanju stikala, desni stolpec – vzrok je v nesklenjenem stikalu

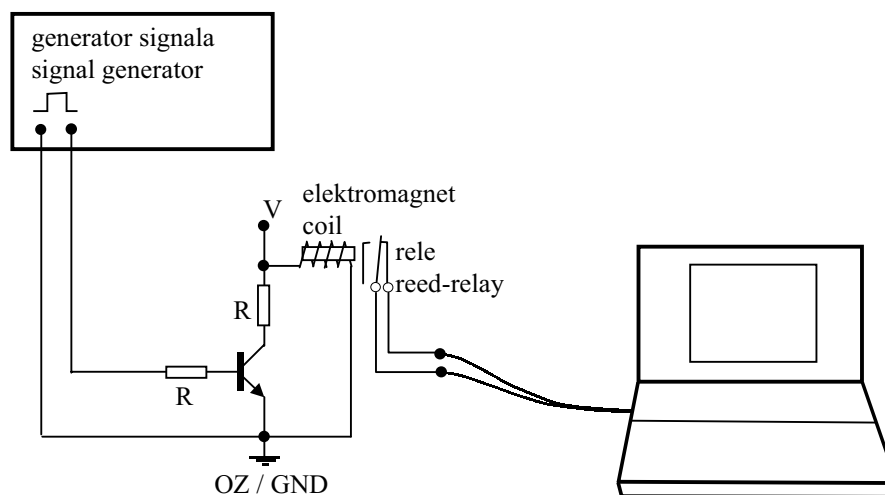
Fig. 5. Examples of erroneous data. Left – due to the switch vibrations, Right – due to missing the switch closure

končnega poročila. Matematični model, ki je bil prikazan v drugem poglavju, je uporabljen v opisanem računalniškem programu skupaj z nadzorom in obdelavo podatkov.

Celoten merilni sistem je bil pred uporabo skrbno preverjen. Preverjen in določen je bil pravilen razmik med magnetom in zaznavalom. Ugotovljeni razmik naj ne bi presegel 10 mm. Signal zaznavala, ki je bil priključen na vzporedni vhod, in program za zbiranje podatkov sta bila preverjena z generatorjem, ki je dajal pravokotne signale z nastavljivimi frekvencami signala. Signal je bil nato ojačen in posredovan tuljavi, ki je vklopila rele (sl.6). To preverjanje je bilo namenjeno določitvi uporabnega področja delovnih frekvenc uporabljenega releja. Odzivnost releja se je izkazala za ustrezno; delovne frekvence so močno presegle pričakovane vrtilne frekvence koles vozila.

report. The mathematical model presented in section 2 is implemented into the software, together with the data supervision and the data smoothing procedures.

The complete measuring system was carefully tested before use. This testing was performed to determine the allowable distance between the magnet and the sensing device, which was found to be up to 10 mm. The sensing device, connected to the parallel port and the software for data sampling, was tested using a rectangular signal generator with a controllable signal frequency. The signal was amplified and applied to the wire coil activating the reed-relay (Fig. 6). This control was performed to determine the applicable reed-relay frequency domain, which was found to be much higher than the expected wheel rotation frequency.



Sl. 6. Shema preverjanja merilne opreme

Fig. 6 Test setup for the measuring device

3 PRIMERI MERITEV MOČI MOTORJA

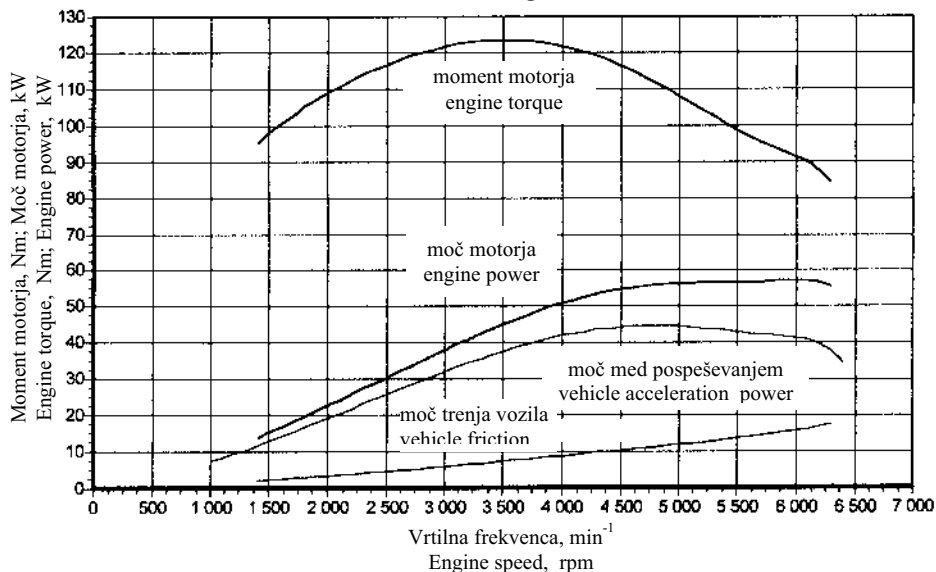
Vzorčno preskušanje metode je bilo v praksi preverjeno na različnih osebnih avtomobilih in opravljeno na vzletni letalski stezi z dolžino 1800 m. Meritve so bile opravljene s tridelnim preskusnim postopkom. V prvem delu se je vozilo ob izklopu pogonskega agregata prosto zaustavljalo; ta del je bil uporabljen za določitev voznih uporov vozila. V drugem

3 MEASUREMENT EXAMPLES

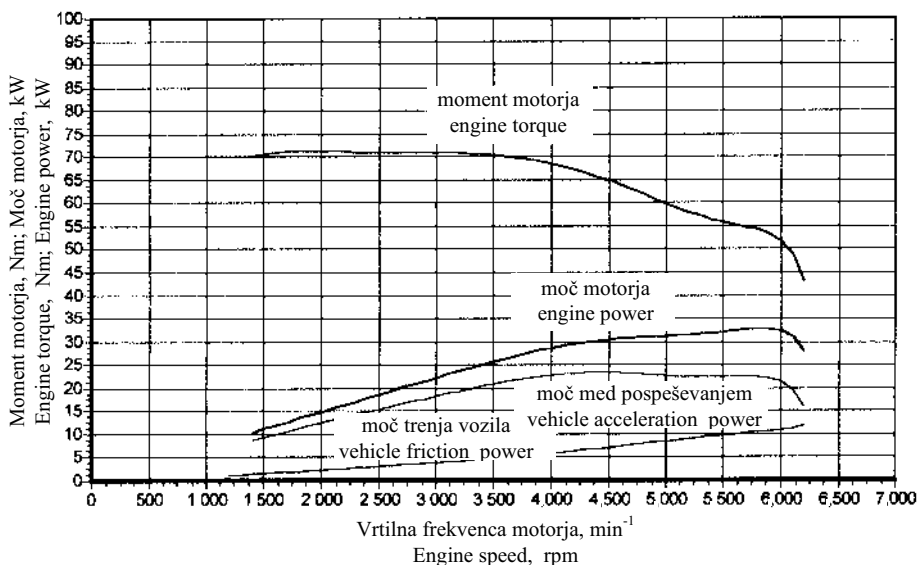
Sample measurements on various passenger cars were performed at a local airport runway with a length of 1800 m. Measurements were performed in three successive tests. The first test was performed using free vehicle deceleration to determine the vehicle's driving resistance. The second and third tests were performed using the vehicle's

in tretjem delu je bilo vozilo pospešeno v drugi oziroma tretji prestavi. Na slikah 7, 8, in 9 so prikazani rezultati meritev na treh različnih osebnih avtomobilih.

acceleration with an engaged engine in 2nd and 3rd gears. Three examples of the results are presented in Fig. 7, 8 and 9.



Sl. 7. Rezultati meritev karakteristik motorja PPP na osebnem vozilu Citroen BX 1.6
Fig. 7. WOT performance for a Citroen BX 1.6



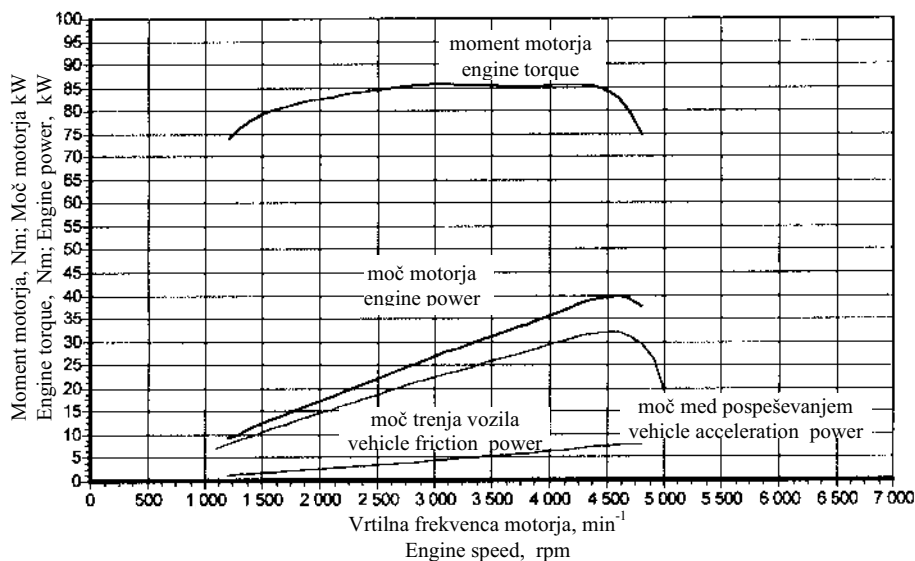
Sl. 8 Rezultati določanja PPP karakteristike motorja na osebnem avtomobilu Renault Clio 1.2
Fig. 8 WOT performance for a Renault Clio 1.2

4 SKLEP

V prispevku je prikazana cenena in praktična naprava za merjenje karakteristike pogonskega motorja vozila PPP. Naprava omogoča hitro določanje moči motorja brez odstranitve katerega koli sestavnega dela v pogonskem sklopu vozila. Takšen postopek določanja moči je cenen in primeren tudi za manjše servisne delavnice; pri tem ni prizadeta nedotakljivost pogonskega sklopa ali njegovih delov in s tem ogrožena veljavnost jamstva izdelovalca vozila. Za izvedbo meritev moči je, v nasprotju z obširno in zelo zahtevno in drago merilno opremo, potrebna le skromna in cenena merilna oprema.

4 CONCLUSIONS

An inexpensive and easy-to-use device for determining a vehicle's engine's WOT performance is presented. The device enables fast measurements of engine performance without any dismantling or disconnecting of the engine or any of the drive train parts. This enables cheap and easy tests for small servicing enterprises without breaking any vehicle warranty conditions and without investing in expensive measuring equipment.



Sl. 9. Rezultati določanja PPP karakteristike motorja na osebni avtomobilu Opel Kadett 1.6D
Fig. 9 WOT performance for a Opel Kadett 1.6D

Predstavljena metoda in postopek zahtevata osebni prenosni računalnik z ustrezno programsko opremo, zaznavalo za določanje vrtilne frekvence koles in ožičenje. Z opisanim sistemom je mogoče zelo natančno določiti karakteristiko moči sesalnega motorja, ki "opravi" prehod na nov režim delovanja v sorazmerno kratkem času.

The presented device consists of a laptop computer, software, a sensor for wheel rotation and wiring. This measurement setup determines very accurate performance figures for naturally aspirated engines due to the very fast transient response of the vehicle's transient. This method is, under certain conditions, also applicable to turbocharged engines.

5 SIMBOLI 5 SYMBOLS

prestavno razmerje prenosnika moči	i		transmission ratio
masni vztrajnostni moment	J	kg·m ²	moment of inertia
prevožena pot vozila	L	m	travelled distance
masa	m	kg	mass
vrtilna frekvenca	n	s ⁻¹	rotation frequency
število vrtljajev kolesa	N		number of wheel revolutions
moč	P	W	power
polmer	R	m	radius
čas	t	s	time
hitrost vožnje po ravnem	v	m/s	linear velocity
časovni korak	Δt	s	elapsed time step
izkoristek	η		efficiency
kotna hitrost	ω	s ⁻¹	angular velocity

Indeksi

pospeševanje	acc
prenosnik moči	dt
upor pri trenju	fr
dejanski	ef
motor	en
motor z vztrajnikom in sklopko	enc
indeks	i
indeks	j
celoten	t
vozilo	v
kolo	w

Indices

acceleration
drivetrain
friction, resistance
effective
engine
engine with flywheel and coupling
index
index
total
vehicle
wheel

6 LITERATURA

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