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DIAGNOSING OF CAR ON THE SHORT ROAD

This article describes methods of calibrating car speedometer on the road without expensive equipment. The most accurate results are obtained by using marking elements, for instance, the standard road guard fence. The most practical method is synchronous video recording of speedometer and the display of receiver for satellite signals GPS or/and GLONASS. Also, the KhNADU has substantiated methods of checking a car for acceleration and running out onto the road with simple measuring devices - a speedometer and a phone stopwatch. Experiments have shown that the real picture of countermeasures does not fit into generally accepted models, and this should be taken into account when calculating the standards of diagnostic parameters - the path and time of run-outing and acceleration. For check of the car by a known method the horizontal section of the road 2.5...3 km long is necessary. On the most part of the territory of Ukraine such sections are very rare, so it is proposed to check up a car on an acceleration on II and III gears and on a coasting down from 50 or 40 km/h to 20 km/h, using accessible length of 0,5 km. Behavior of car in such conditions was studied, some unknown specificities are discovered and described. The methods of calculation of control values for time of acceleration and time of coasting are offered. The speedometer is a frequency converter of the output shaft of the transmission or the wheels of the car. It inevitably reflects all the errors caused by the uncertainty of the rolling radius of the wheel, including due to atmospheric conditions, the degree of tire warm-up, vehicle loading and its distribution in the longitudinal and transverse directions, etc. Under these conditions, it is necessary to improve the standless diagnostic methods available to ordinary drivers, i.e. on-the-road inspection methods without complicated or prohibitively expensive equipment. So the calibration of the speedometer is a necessary test step and, in critical cases, must be performed at the beginning and end of each test day. Experimentally estimated the error, the required duration of measurement and speed variation when maintaining it by driver or by cruise control. Grading on GPS better when driving south. Calibration equation was obtained for the 2006 Honda Civic: $V_{GPS} = 0{,}9528\ V_{speedo}. - 0{,}83$.

Keywords: short road, car test, acceleration time, coasting time, GPS, car, speedometer.

INTRODUCTION

In operation, the performance of cars is gradually deteriorating, which must be detected in a timely manner. This problem is solved with the help of traction roller stands. However, traction stands are expensive and many service stations do not have them. Service station owners believe that there is no demand for such services: a client arrives with a specific complaint about the deterioration of the technical condition, and the service station is required not to confirm this fact, but to search for and eliminate a defect that causes the car to become inoperable. Another argument is that a modern car has on-board diagnostic tools and therefore does not need external diagnostics. Both of these arguments are invalid.

The driver turns to the service station when he noticed a deterioration in the traction properties of the car and could not fix it on his own. But the experience of drivers is not always enough to detect this deterioration in a timely manner. There are cases when the driver noticed a decrease in traction properties by two or even three times. But at the same time, the car does not just “drive badly” - it wastes fuel, i.e. non-renewable natural resources, and this is no longer a personal concern of the car owner, but a problem for the whole society.

References to the equipment of a modern car with on-board diagnostics are irrelevant for Ukraine. The average age of the country's passenger car fleet is 18.5 years, which means that half of all cars are even older. So most of the cars in our countries do not have on-board diagnostics.

KhNADU substantiates methods for checking a car for acceleration and run-out on the road with simple measuring tools - a speedometer and a phone stopwatch. Experiments have shown that the real picture of resistances does not fit into generally accepted models, and this should be taken into account when calculating the standards for diagnostic parameters - the path and time of run-out and acceleration. It is recommended to accelerate to 100…120 km/h in direct or IV gear, followed by coasting to a stop. But for such tests, horizontal sections of the road 2.5 ... 3 km long are needed. We have such sites are very rare. Therefore, it is proposed to check cars on a short road in terms of acceleration time in downshifts and run-out time from 50 or 40 to 20 km/h.

ANALYSIS OF LITERARY DATA AND PROBLEM STATEMENT

The car develops the maximum traction force of interest to the diagnostician at maximum speed, with very high resistances or during acceleration. The easiest way to do an acceleration road test is in calm weather on a level road with good coverage. We will not determine the absolute value of the traction force

P_T, but we will know that, minus the total road resistance P_T and air resistance P_W, this force is sufficient to give a car with a mass m an acceleration a, that is

$$P_T - P_\Psi - P_W = ma. \qquad (1)$$

The average acceleration is a fairly objective indicator, it is easy to evaluate it without special instruments: for example, put the car into direct gear, develop a speed of 50 ... increasing speed from V_1 to V_2, say from 60 to 100 km/h. If the length of the measured section of the road is insufficient, then acceleration should be carried out in downshifts.

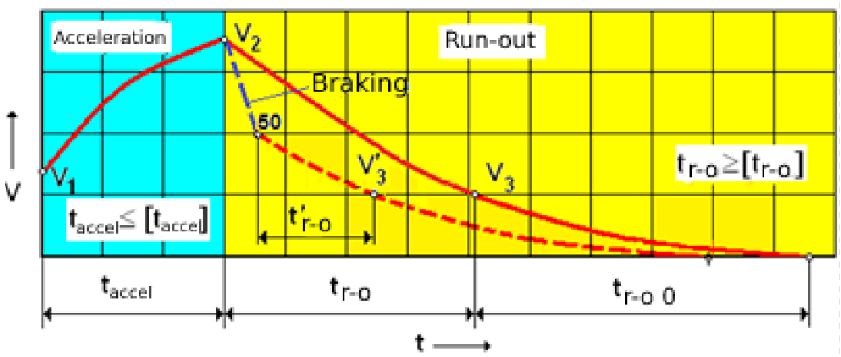

Figure 1. Scheme of general diagnostics of the traction and speed properties of the car for acceleration and run-out
(solid lines - known method, dashed lines - proposed)

After the end of acceleration, i.e. reaching speed V_2, you can disengage the clutch and measure the car's run-out time, i.e. coasting from V_2 to V_3 and/or to a stop. If the measured road is short, you can first slow down, for example, up to 50 km/h, and then start the car coasting. The deceleration of the run-out characterizes the sum of external resistances plus losses in the suspension and disconnected transmission. To assess the technical condition of the car, it is these losses that are of interest.

Coasting distances are given in the literature (usually from 50 km/h to a stop). The coast down path can exceed 1000 m, so it is better not to bring the coast to a stop, but to limit it to some small speed range, for example, from 50 or 40 to 20 km / h. But measuring the run-out distance on the odometer in this case is too rough (the absolute error is 100 m with a full path of 300 ... 500 m. It's easier to measure not the path, but the run-out time.

In order to use the obtained values of the acceleration and run-out times as diagnostic parameters characterizing the technical condition of the car, it is necessary to have standards (control values) for these indicators. And to calculate the standards, it is necessary to study the features of the car in the selected modes and, accordingly, adjust the theory of movement.

AIM AND TASKS OF THE RESEARCH

The purpose of this work is to improve the standless diagnostic methods available to ordinary drivers, i.e. on-road testing methods without sophisticated or prohibitively expensive equipment and a general familiarization with them.

RESEARCH RESULTS

For the case of operation at full fuel supply, i.e. according to the external speed characteristic of the engine (ESCE), the tractive force P_t in newtons is calculated from the curve of the effective torque M_e in newton meters:

$$P_T = \frac{M_e \cdot u_i \cdot u_0 \cdot \eta_T}{R_d}, \qquad (2)$$

where u_i is the gear ratio of the i-th gear engaged;
u_0 - gear ratio of the main gear (main pair)
η_T is transmission efficiency;
R_d is the dynamic radius of the driving wheel, m.

The torque curve M_e is found in the literature. For old carburetor and diesel engines, it can be calculated using the well-known formula S.R. Leiderman:

$$M_e = M_{eN\max}\left[A + B\left(\frac{n}{n_N}\right) - C\left(\frac{n}{n_N}\right)^2\right] \qquad (3)$$

where $M_{eN\max}$ is the torque at rated (maximum) power, Nm;

n – crankshaft speed (crankshaft) current, min^{-1};

n_n is the speed of rotation of the crankshaft at the rated (maximum) power, min^{-1};

A, B, C - coefficients, individual for each engine and depending on its coefficients of adaptability in terms of rotation frequency of the crankshaft and in terms of torque. Many methodological sources recommend the same coefficients for all carburetor engines and somewhat different ones, but also the same for all diesel engines. In this version, the formula gives a satisfactory power curve, but not torque - the torque curve calculated in this way does not even pass through the points of maximum torque and rated power specified in the vehicle and engine characteristics.

For modern electronically controlled engines, the Leiderman formula gives satisfactory results only in a limited range of rotational speeds, for example, from 2500 to 4500 min^{-1}.

However, the nominal torque curves published in the literature were obtained in static modes, i.e. according to measurements at each point at a constant speed, without acceleration. Acceleration during acceleration noticeably distorts the configuration of the torque curve (Figure 2). The entire curve descends slightly, dips appear at the beginning and end, and the point of maximum moment shifts along the abscissa axis to the right or left.

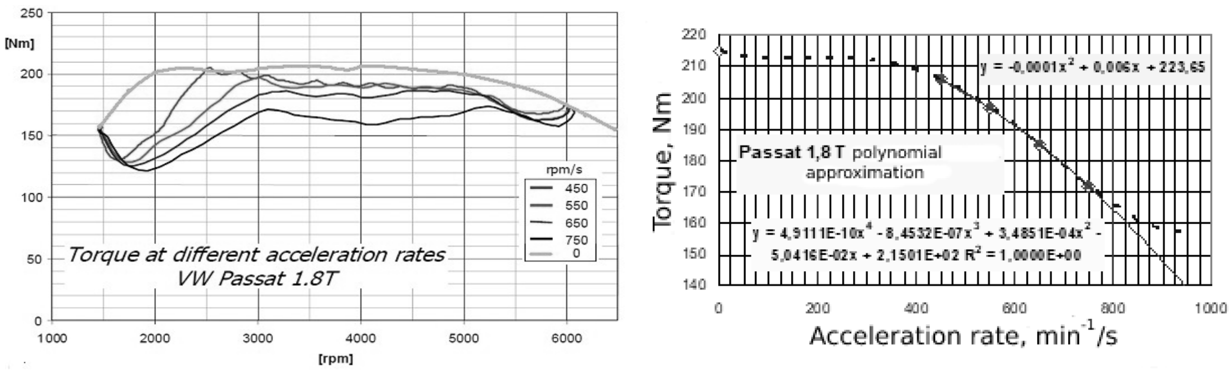

Figure 2. Torque measurement results for VW Passat 1.8 T
on the Rototest VPA-RX 2WD [1] (left) and our processing [2]

The engine acceleration rates (450…750) used by the Rototest researchers are not exaggerated. So, in our experiments, a car Lada 111 weighing 1260 kg accelerated in second gear at a rate of 320…360 min–1/s, and in first gear – 920…1080 min–1/s.

DVS theory explains this reconfiguration verbally, not quantitatively. It is not even clear where the maximum torque will shift - to the right, to higher crankshaft speeds, or to the left. Prof. A.N. Poida believes that this sets the engine setting, which is manifested by the shape of the torque curve according to the ESCE. If the curve has a clearly defined maximum (as, for example, in the Lada Priora car), one should expect a shift to the left, but if there is a platform (as in the VAZ-2111), the maximum will shift to the right. Note that for cars of the Volkswagen Audi Group, the maximum is usually shifted to the right.

The generally accepted models of resistance to vehicle movement simplify the real picture. This is shown by the processing of published field test data (Figure 3). Discrepancies appear in all speed ranges, which indicates an insufficiently accurate description of all acting forces[3].

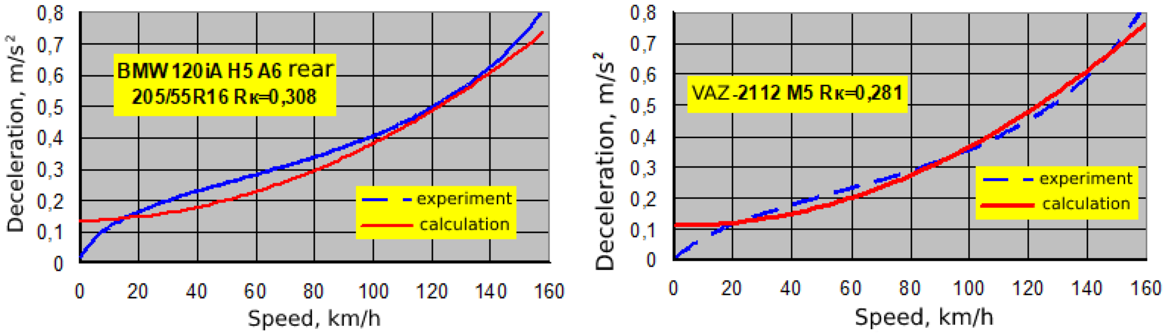

Figure 3. Comparison of calculated and experimental dependencies
deceleration of the free run of cars from speed
(processing of the results of field tests "Autoreview")

Note that these discrepancies are not the result of incorrect processing. The results of our experiments on different cars have a very similar configuration. The speed dependence of the DAEWOO Matiz 0.8 car deceleration (Figure 4) built on the basis of experimental data has exactly the same shape as shown in Figure 3, in particular, a clearly pronounced decrease in the deceleration module (i.e., resistance forces) on speeds below 20 km/h. Since this diagram was built using the data of 21 runouts - both upwind and downwind, and on two different roads (i.e. at different angles to the direction of the wind), such a deviation from the theoretical diagram cannot be attributed to incorrect processing, negligence performers, wind influence, unaccounted for slope, random factors, etc.

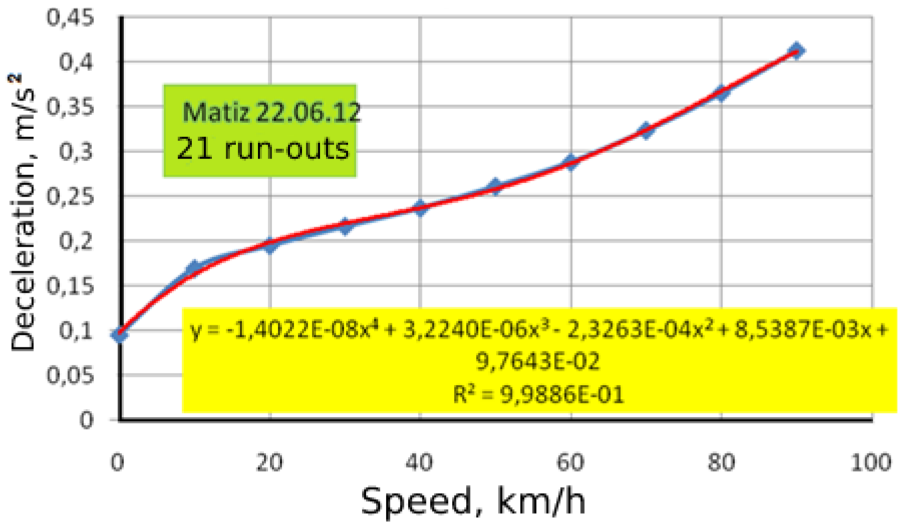

Figure 4. Experimental dependence averaged over 21 run-outs

Calm periods on open roads are extremely rare, so you can not completely clear the results from the influence of the wind. But with a weak wind (about 1 m/s), similar rundown diagrams were obtained in both directions, with a clear drop in resistance at low speeds, especially below 8...10 km/h (Figure 5). Consequently, this feature of the resistance to vehicle movement at low speeds can be considered proven and taken into account in the calculations.

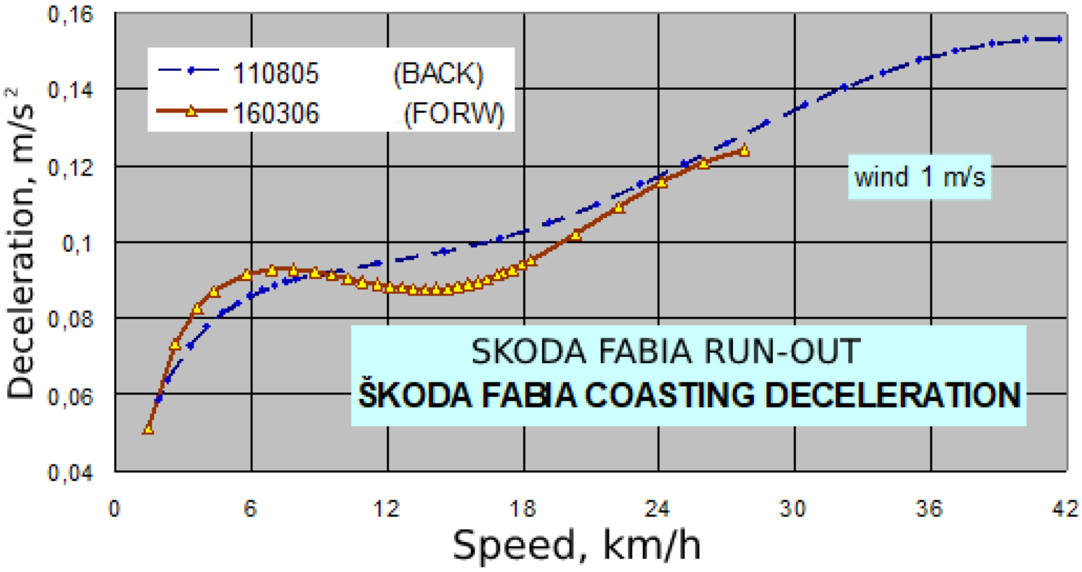

Figure 5. Experimental dependences of the deceleration of the car Skoda Fabia Combi I on the speed when coasting in opposite directions

This drop can be caused by the peculiarities of all acting forces. Idling losses of the transmission depending on the speed are usually described by a linear law (V.V. Moskovkin et al.). However, our experiments show a progressive decrease in these losses as the speed decreases (Figure 6).

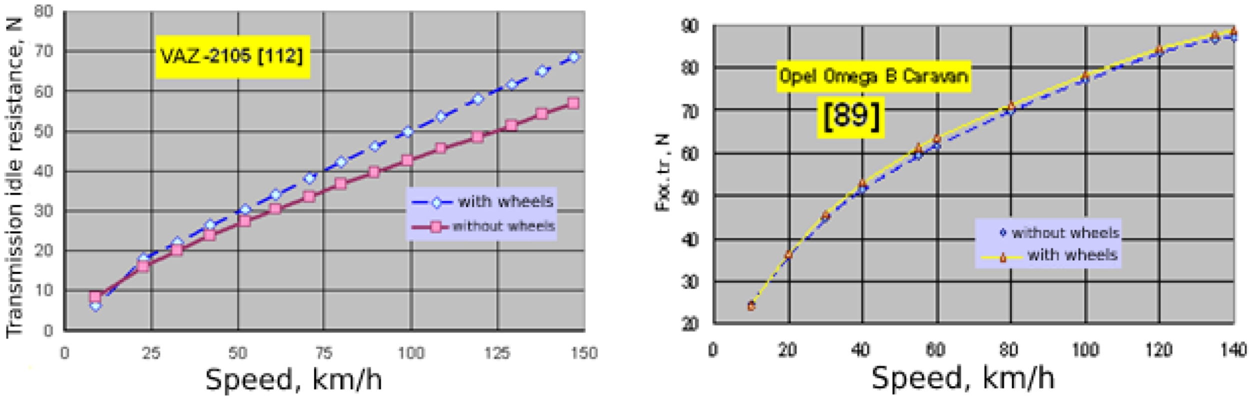

Figure 6. Idling resistance of a passenger car transmission

Many sources suggest that the rolling resistance coefficient be considered constant in the range from zero to 100 km/h. More conscientious authors simply do not show its values at speeds below 15 km / h (Figure 7) - apparently, due to the peculiarities of the measuring systems of tire stands. But even in these cases, the downward deviation of the experimental points is clearly visible [4].

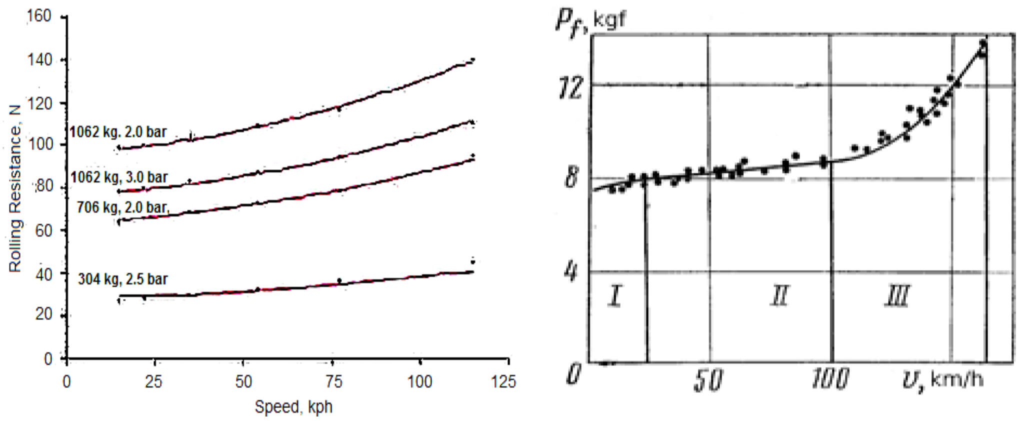

Figure 7. Dependence of rolling resistance on speed according to [5].

Air resistance to vehicle movement is usually described as a quadratic dependence on speed:

$$P_w = 0{,}5\rho_w \cdot C_x \cdot F \cdot v^2, \qquad (4)$$

where ρ_w is the air density, on average 1.2 kg/m^3;
C_x is the drag coefficient;
F is the frontal area of the vehicle, m^2;
v is the speed of the vehicle relative to the air, m/s.

It is generally accepted that when blowing in a wind tunnel, the coefficient C_x is measured. In fact, the forces and moments acting on the object along three axes and the flow velocity are measured, and C_x is calculated based on formula (4), i.e. a priori taking the exponent equal to 2. In fact, the exponent is not equal to 2 and is not a constant at all. It essentially depends on the speed, it was shown back in the 20s of the last century, this is well known to specialists. However, the literature does not provide guidance on how to calculate it. We tried to explore its connection with the speed of the means available to us. It turned out that the qualitative picture of 84 studied cars is almost the same, although the variation is very large, especially at speeds below 20 km/h. But the absolute values of the force Pw are small here, so you can use the averaged dependencies shown in Figure 8.

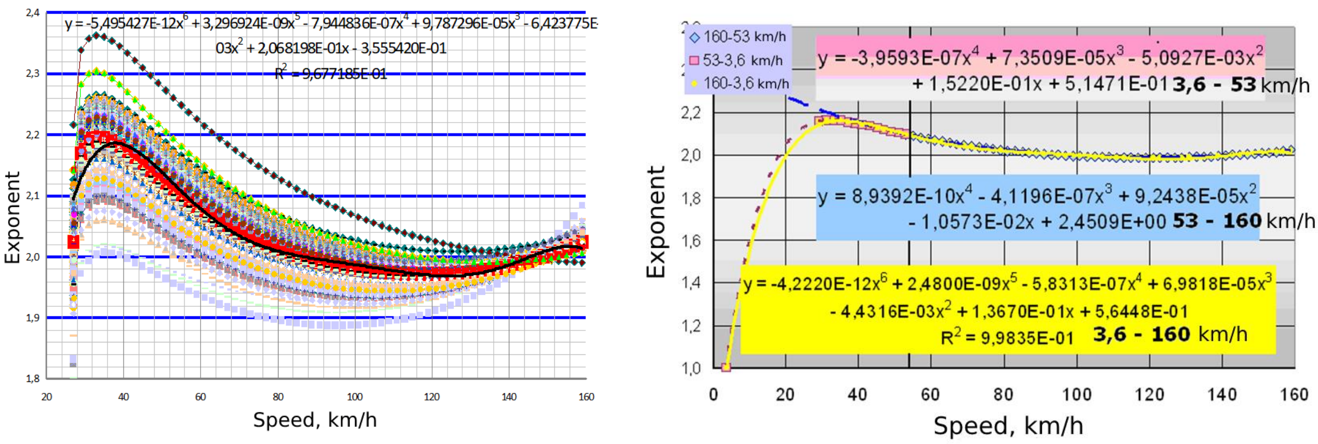

Figure 8. The dependence of the exponent in the air resistance formula on speed: variation across different vehicles (left) and polynomial approximation [6].

DISCUSSION OF THE RESEARCH RESULTS

Traction balance equation (1) is essentially a differential equation of the form

$$\mathrm{a} = \frac{dv}{dt} = \frac{P_m - \Sigma P_c}{m_a \cdot \delta}, \qquad (5)$$

where a is the acceleration of the vehicle, m/s^2;
$\sum P_c$ is the sum of resistance to movement, N;
ma is the progressively moving mass of the vehicle, kg;
δ is the coefficient for accounting for rotating masses.

Traditionally, all components of the traction balance are described by polynomials of no higher than the second degree. In this case, the differential equation is solved in general form. But if we take into account the refinements of the mathematical models of these components described above, then the equation becomes much more complicated:

$$\frac{dV}{dt} = \left[\begin{array}{l} \dfrac{M_e u_i u_0 \eta}{r_{ko} - \lambda_M M_e u_i u_0 \eta} - 0{,}5\rho C_x F \cdot \left(\dfrac{v}{3{,}6}\right)^{(8{,}94\cdot10^{-10}v^4 - 4{,}12\cdot10^{-7}v^3 + 9{,}24\cdot10^{-5}v^2 - 0{,}01057v + 2{,}45)} \\ -\left(1{,}3G_a - 1{,}2q_{tp}\right)\cdot(-1{,}4\cdot10^{-8}v^4 + 3{,}22\cdot10^{-6}v^3 - 2{,}33\cdot10^{-4}v^2 + 0{,}00854v + 0{,}098) \end{array} \right] \cdot \frac{1}{\delta \cdot m_a},$$

(6)

$$M_e = 2{,}29\cdot10^{-19}n^6 - 5{,}76\cdot10^{-15}n^5 + 5{,}78\cdot10^{-11}n^4 - 2{,}94\cdot10^{-7}n^3 + 7{,}9\cdot10^{-4}n^2 - 1{,}0376n + 65{,}504,\ n = \frac{v\cdot u_i u_0}{0{,}377\left(r_{ko} - \lambda_M M_e u_i u_0 \eta\right)}.$$

In this form, it does not have a general solution, but is easily solved by numerical methods, for example, by the well-known finite difference method. The method is simple, clear and easy to use. Its key point is the choice of the discretization step of the considered range of the argument (in our case, the speed) when constructing the grid. The analysis showed that too small a step is not required to calculate the acceleration or run-out time: for example, a calculation error of less than 1% is provided at a step of 20 km/h, and an error of less than 0.1% is provided at a step of less than 6.4 km/h (Figure 9) [7].

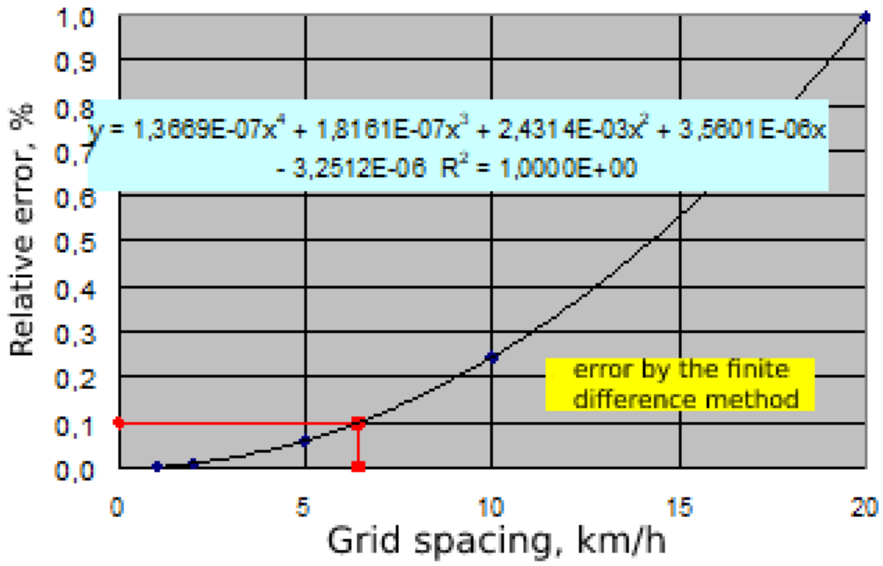

Figure 9. Dependence of the calculation error by the finite difference method on the grid step [8].

The standard values of the acceleration time and the run-out time are calculated as solutions of the differential equation of motion by the finite difference method for given boundary conditions (for example, v_1=60, v_2=100).

The standards should be calculated for specific test modes. Based on calculations and experiments, the following modes are recommended: acceleration in third gear from 50 to 100 km/h, in second gear from 20 to 80 or to cutoff; rear-wheel drive vehicles can be additionally checked by acceleration in gear I from zero to 40 km / h or to a cutoff. Run checks from 50 or 40 km/h to 20 km/h [9].

The difficulty in calculating the acceleration is the choice of the torque curve equation, taking into account the influence of the acceleration of the KV and the age of the engine. Our research allowed us to propose empirical corrections that bring the results of calculating the acceleration time according to the nominal torque curve closer to the experimental results. We recommend taking into account the reduction in the maximum torque in the lower gears (accepted within 8%) by the coefficient

$$K_1 = 1 - 0{,}02\cdot u_i, \qquad (7)$$

where ui is the gear ratio of the gear for which the calculation is being carried out.

Assume that the largest displacement of the point of maximum torque Δn_M along the axis of the rotation frequencies of the crankshaft is 1000 min–1 in the lowest gear. Calculate the specified offset using the formula

$$\Delta n_M = \pm 275 u_i. \qquad (8)$$

In addition, it is known that as the cylinder-piston group wears out, the branches of the torque curve to the right and left of the maximum point fall steeper and steeper. It is recommended for vehicles that are in operation for T years from the date of issue or overhaul to enter a reduction factor into the torque formula

$$K_2 = 1 - T \cdot [0{,}006 + 0{,}010 \cdot (n / n_M - 1)^2], \qquad (9)$$

where n_M are the maximum torque revolutions, min^{-1}.

The smallest discrepancy with the experimental data is given by the calculation of the acceleration standards according to the nominal torque curve, approximated by a polynomial of the 6th degree, with the indicated empirical corrections.

CONCLUSIONS

The study showed the possibility of diagnosing cars on a short road by accelerating in II-III gears and coasting from 50 or 40 km/h to 20 km/h. This greatly expands the possibilities of using such diagnostics in operation. In the course of the study, new results were obtained that made it possible to improve the theory of car movement.

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Ю.В. Зибцев, П.А. Ворошилов. ***Діагностика автомобіля на короткій дорозі***

У цій статті описані способи калібрування спідометра автомобіля в дорозі без дорогого обладнання. Найбільш точні результати дає використання елементів розмітки, наприклад, стандартної огорожі. Найпрактичішним способом є синхронний відеозапис спідометра та дисплея приймача супутникових сигналів GPS та/або ГЛОНАСС. Також у ХНАДУ обґрунтували методи перевірки автомобіля на розгін і вибіг по дорозі простими вимірювальними приладами – спідометром і телефонним секундоміром. Експерименти показали, що реальна картина протидії не вкладається в загальноприйняті моделі, і це слід враховувати при розрахунку стандартів діагностичних параметрів - шляху і часу вибігу і прискорення. Для перевірки автомобіля відомим методом необхідна горизонтальна ділянка дороги довжиною 2,5...3 км. На більшій частині території України такі ділянки зустрічаються дуже рідко, тому пропонується перевіряти автомобіль при розгоні на II та III передачах та накаті від 50 або 40 км/год до 20 км/год, з використанням доступної довжини 0,5 км. Вивчено поведінку автомобіля в таких умовах, виявлено та описано деякі невідомі особливості. Запропоновано методи розрахунку контрольних значень часу розгону та часу вибігу. Спідометр - це перетворювач частоти вихідного вала коробки передач або коліс автомобіля. У ньому неминуче відображаються всі похибки, викликані невизначеністю радіуса кочення колеса, в тому числі через атмосферні умови, ступінь прогріву шини, навантаження автомобіля і його розподіл в поздовжньому і поперечному напрямках і т. д. За цих умов необхідно вдосконалити доступні звичайним водіям автономні методи діагностики, тобто методи огляду на дорозі без складного або не дуже дорогого обладнання. Отже, калібрування спідометра є обов’язковим етапом тестування, і в критичних випадках воно має виконуватися на початку та в кінці кожного дня тестування. Експериментально оцінено похибку, необхідну тривалість вимірювання та зміну швидкості при її підтримці водієм або круїз-контролем. Оцінка за GPS краще під час руху на південь. Калібрувальне рівняння було отримано для Honda Civic 2006 року: V_{GPS} = 0,9528 V_{speedo}. – 0,83.

Ключові слова: коротка дорога, випробування автомобіля, час розгону, час руху накатом, GPS, автомобіль, спідометр.

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