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Computer Simulation of Transitional Performance of an Engine During Curvilinear Motion of Motor-Vehicle in Intersection

KEYWORDS: effective engine moment, transitional performances, dynamic and static characteristics, cyclic fuel supply

Ivanka Moneva

Technical University of Sofia, Faculty and College in Sliven, 8800 Sliven, Bulgaria

ABSTRACT *A comparative analysis of the effect of mathematical models of transitional performances in internal combustion engines upon the change of motor-vehicle dynamic and kinematic parametres is done in this study. A mathematical model of transition performance by the change of the effective engine moment and a mathematical model of transition performance by the change of fuel supply versus time are presented. The operation of engine and motion of motor-vehicle are presented through a system of differential equations that is solved by the means of programme product MATLAB. The results of the numerical experiments are shown graphically.*

Introduction

In the modern world of a quick raise of motorization an important aim for the insurance of safety on the road is the enlargement of technical activities. This is grounded on the planning and design of communication and transport systems (the street network) of the urban regions. The examinations of the normative documents show the increase of vehicles to be about 550-600 personal cars for 1000 citizens in a populated location up to the year 2020.

The correct account of the vehicles technical parametres during the design of communication and transport systems insures time savings, ecology and travelling convenience and safety on the road.

One of these parametres is the time for passing through intersection, and especially during vehicle curvilinear motion. This process is connected with engine operation at transition performance.

The operation of the system "engine/motor-vehicle" and the change of the kinematic parametres of a motor-vehicle running in curvilinear motion in intersection are presented in this study by variable mathematical models of engine transitional performance.

Dynamic Model

The quality of transitional performances is determined by special indices. One of the most important indices is the parametre transitional performance time, i.e. the time interval in which an engine passes from one settled operation regime into another. The less time, the higher quality of transition performance.

Numerical dynamic models of engine operation in transitional performance for determining the dynamic and kinematic parametres of motor-vehicle motion in different road conditions and sections are created.

In Ref. 3 the engine operation in transitional performance is presented by the change of the effective engine moment. This change is mathematically described by two sections of transition from one to another partial velocity characteristic of the engine

(1)
$$M_d = a_1 + a_2 \cdot q + a_3 \cdot \omega_d + a_4 \cdot q^2 + a_5 \cdot \omega_d^2 + a_6 \cdot q \cdot \omega$$
$$M_d = b \cdot \omega_d$$

Where $a_1, a_2, a_3, a_4, a_5, a_6, b$ are approximation coefficients; ω_d is the angular velocity of engine crankshaft.

For the drawing up of this model the procedures for approximation of the static characteristics of the system units for automated adjustment of frequency of crankshaft rotation and building of transitional performances propounded by prof. V. I. Krutov are used.

A mathematical model of transition performance in the combustion apparatus of an engine is shown in Ref. 4. The change of fuel supply is presented by the dependence

(2)
$$q(t) = q_0 + q_1 \cdot \left(1 - e^{at}\right),$$

where is cyclic fuel supply; q_0 is the initial value of cyclic fuel supply; q_1 is the value of raise of cyclic fuel supply up to a settled regime; a is time-constant determining the duration of cyclic fuel supply in transition performance.

The engine operation is presented with its basic differential equation of motion composed in accordance with D'Alembert's Principle, and is of the form

(3)
$$I_d \cdot \frac{d\omega_d}{dt} = M_d - M_c$$

where I_d is the mass moment of inertia of all rotating masses reduced to the crankshaft; M_d is an effective engine moment; M_c is a resistance moment reduced to the crankshaft.

The mathematical models describing the engine operation in transition performances are adapted by computer modulus in the basic computer simulation programme in MATLAB, represented in details in Ref. 1 and 2.

The motor-vehicle is considered as a mechanical system "automobile body/wheels" with generalized coordinates , x_C, y_C, coordinates of motor-vehicle mass centre; φ is an angle of engine turning around the central vertical axis z read from the x-axis; γ is an angle of wheels rotation round their own axis; θ is an angle of wheels rotation round their corresponding steering knuckle axis. Fig. 1 depicts a mo-

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tor-vehicle during regime of working at idle running.

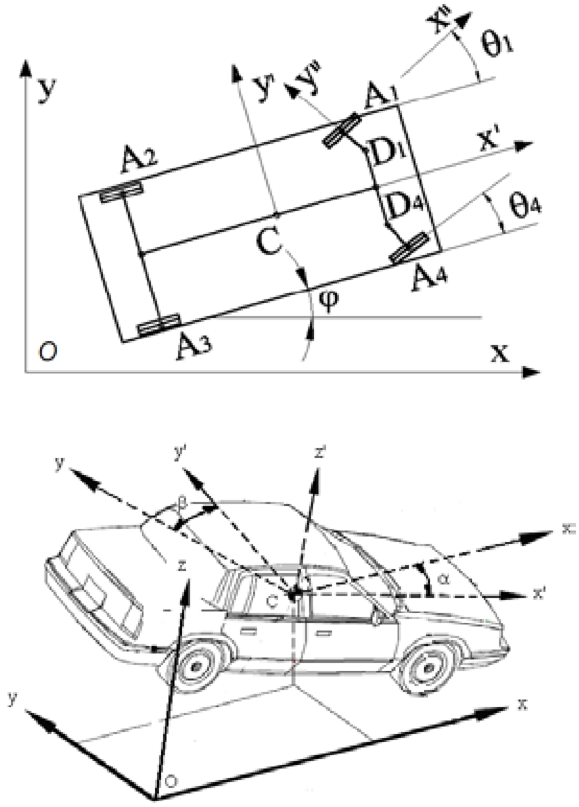

Fig. 1. A scheme of motor-vehicle in general situation

The differential equations of motor-vehicle motion are represented in the form

$$m\cdot\ddot{x}_C=\sum_{i=1}^{4}\left[F_{ix}\right]+m\cdot g\cdot\sin\alpha-w_x\cdot\sqrt{\dot{x}_C^2+\dot{y}_C^2}\cdot\dot{x}_C\,;$$

$$m\cdot\ddot{y}_C=\sum_{i=1}^{4}\left[F_{ix}\right]+m\cdot g\cdot\sin\alpha-w_y\cdot\sqrt{\dot{x}_C^2+\dot{y}_C^2}\cdot\dot{y}_C\,;$$

$$I_C\cdot\ddot{\varphi}=\sum_{i=1,4}\begin{bmatrix}F_{iy}\cdot\begin{pmatrix}x_i'\cdot\cos\varphi-y_i'\cdot\sin\varphi+\\+l_o\cdot\sin\varphi-l_o\cdot\sin(\varphi+\theta)\end{pmatrix}-\\-F_{ix}\cdot\begin{pmatrix}x_i'\cdot\sin\varphi+y_i'\cdot\cos\varphi-\\-l_o\cdot\sin\varphi+l_o\cdot\sin(\varphi+\theta)\end{pmatrix}\end{bmatrix}+\sum_{i=2,3}\begin{bmatrix}F_{iy}\cdot(x_i'\cdot\cos\varphi-y_i'\cdot\sin\varphi)-\\-F_{ix}\cdot(x_i'\cdot\sin\varphi+y_i'\cdot\cos\varphi)\end{bmatrix};$$

$$\left[I_\gamma\right]\cdot\left[\ddot{\gamma}_i\right]=\left[M_\gamma\right];\left[M_\gamma\right]=F_{i\tau}\cdot r_i+\mathrm{sign}(\dot{\gamma}_i)\cdot\left[M_{d_k}-f_i\cdot N_i-M_{si}\right],$$

$$I_\theta\cdot\ddot{\theta}=\sum_{i=1}^{2}\left[M_{s_i}+M_{j_i}\right]+M_r,$$

where **m** is the motor-vehicle mass; I_C is the motor-vehicle moment of inertia towards its vertical axis; F_i are friction forces in wheels; r_i are wheels dynamic radii; g is gravity; α,β are road slope angles on the x and y axes, respectively, positive when moving downhill and negative when moving uphill; w_x, w_y are streamline factors for determining the air resistance force; x_i', y_i' are wheel center coordinates on the movable coordinate system; $\gamma_i\,/i=1\div4/$ are angles of wheels swiveling around their own axes; I_γ are reduced wheels moments of inertia towards their axes of rotation;M_{si} are brake moments; N_i are normal reactions in the wheels;I_θ are reduced moments of inertia of the driving wheels towards the steering knuckle axes; θ is mean angle of wheels rotation round their steering knuckle axes; M_{s_i} are the stabilizing moments of the road surface from the left and right driving wheels; M_{j_i} are the moments of inertia forces of the left and right driving wheels; M_r is a mment of resistance force occurring in the rack; M_{dk} is reducadengine moment towards wheels.

Numerical Experiments

A case of motor-vehicle curvilinear motion during passing in intersection with accelerating of II[nd] gear at initial velocity $V_0=5\ \frac{m}{s}$ for time $t=5\ s$ is considered. The transition performance goes on up to reaching a settled regime. The investigation is done with the characteristics (1) and (2) describing the transition performance.

The differential equations of engine operation (3) and motor-vehicle motion (4) are solved by means of the programme product MATLAB.

Results for the change of the dynamic and kinematic parametres of motor-vehicle for two mathematical models of transition performance are obtained.

The change of the motor-vehicle discreet positions in intersection is shown in Fig. 2 at characteristic (1) and characteristic (2), respectively.

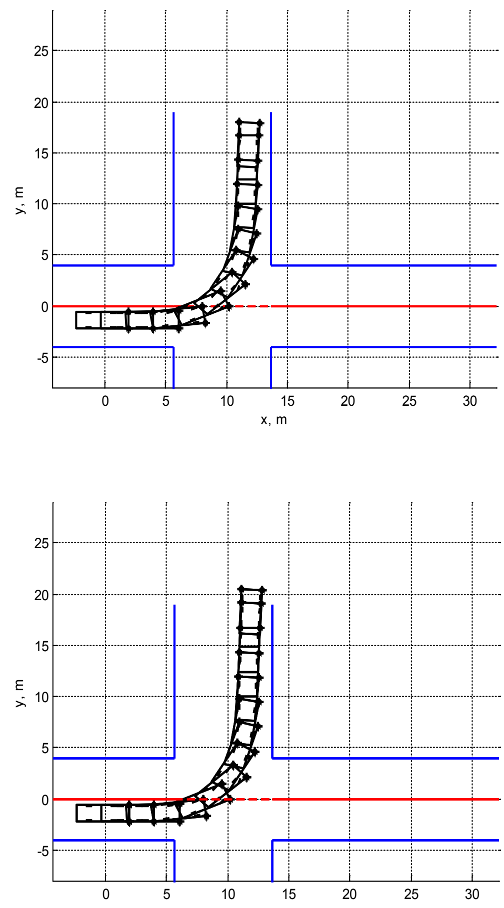

Fig. 2. A time dependence of change of motor-vehicle discreet positions.

An Analysis of Results

The analysis of the results shows a realization of higher values of the travelled route in the intersection (S = 33 m at y = 21 m), velocity and acceleration if the transition performance is assigned with mathematical model (2). The values of parametres obtained with model (2) are about 10 %

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higher than those got with model (1).

The results of the suggested two models of transition performance allow recommendations to be done for the next nature experiments for the choice of a mathematical model adequate to the real processes.

The necessity of creating of adequate mathematical models is due to the necessity for the increasing the efficiency of engine operation. This can be reached by improving the transitions performance of an engine.

The results from the analysis manifest the expedience of scientific and practice developments of methods of approach and means ensuring an optimization of the transitional performance process in the system "engine/motor-vehicle".

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