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Analytical Investigation of Motor-Vehicle Kinematics Parametres at Acceleration During Rectilinear Motion

KEYWORDS: transitional operation modes, velocity and acceleration of motor-vehicle, rectilinear motion, external and partial velocity characteristics of internal combustion engine

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ABSTRACT *A procedure for analytical investigation of the velocity indices (velocity and acceleration) at motor-vehicle acceleration during rectilinear motion is hold out in this study. The results obtained by the numerical experiment are presented graphically, and their adequacy with the natural experiment is demonstrated.*

Introduction

The transitional (unsettled) operation modes of motor-vehicles are a significant part of motion time in urban and out-of-town conditions during maneuvers requiring gear shifting. The main indices of the transitional operation modes of motor-vehicle are the changes of velocity and acceleration.

The goal of this study is the formation of a procedure for analytical determination of motor-vehicle kinematics parameters at rectilinear motion during the start from out-of-motion position up to the reach of settled operation mode at a certain gear.

Mathematical Modeling

A priority of analytical determination of motor-vehicle basic velocity properties such as velocity and acceleration is that the mathematical dependences give a possibility for numerical examinations of a wide spectrum of motor-vehicles.

The modeling of transitional operation modes of a motor-vehicle during engine work at external velocity characteristic is not precise, and therefore it is necessary the transitions upon the partial characteristics at incomplete fuel-feeding to be read. In this connection the engine is described with a characteristic representing the moment in a dependence of two parameters, n and γ, the frequency of rotation of engine crankshaft and the position of fuel-feeding pedal, respectively. This dependence is obtained as a result of the approximation of the experimental data represented in [1].

(1)

$$M_d = f(n, \gamma)$$

The procedure for the carrying out of numerical investigations for the obtaining of engine moment change at transitional operation modes is described in details in [2].

The motor-vehicle rectilinear motion is described using the equation of motor-vehicle during clear rolling of wheels got in article [3].

$$\ddot{x} = \frac{1}{\left(m + \frac{I_1 + I_2}{r^2}\right)} \cdot \left[\frac{M_d}{r} - m \cdot g \cdot (f \cdot \cos\alpha \pm \sin\alpha) - w \cdot \dot{x}^2\right]$$

(2)

where m is motor-vehicle mass; I_1 and I_2 are the mass moments of inertia of the drive and driven gears, respectively; M_d is the motor moment deduced towards the axes of wheels; g is acceleration of gravity; f is a of rolling resistance coefficient; w is the factor of streamlining; α is the angle of road longitudinal slope.

The motion of motor-vehicle with cutch slippery at gear change is described with integral-differential systems of equations, represented in details in [2].

$$I_d \cdot \ddot{\varphi}_d = M_i(\dot{\varphi}_d) - M_M(\dot{\varphi}_d) - M_r(t)$$

$$I_{a_j} \cdot \ddot{\varphi}_c = M_r(t) - M_s(\dot{\varphi}_c)$$

$$A_b = \int_0^t M_r(t) \cdot (\dot{\varphi}_d - \dot{\varphi}_c) \cdot dt$$

(3)

where $\dot{\varphi}_d$ is the angular velocity of crankshaft; $\dot{\varphi}_c$ is the angular velocity of clutch shaft; I_d is the mass inertia moment of the motor-vehicle engine reduced to the crankshaft; I_{a_j} is the mass inertia moment of the motor-vehicle of the j^j-gear reduced to the clutch shaft; $M_i(\dot{\varphi}_d)$ is an indicator torque of the engine; $M_M(\dot{\varphi}_d)$ is a moment of mechanical losses in the engine; $M_s(\dot{\varphi}_c)$ is the resistance moment caused by the external load supplied upon the engine shaft; $M_r(t) = \psi.t$ is the friction moment of the clutch; ψ is a coefficient reading the speed of increase of clutch friction moment; A_b is the slippery work of the clutch.

The developed mathematical model is realized in a medium of imitation-mathematical modeling of dynamic systems Simulink of the programme product Matlab. The model includes the following basic stages:

I – engine operation in a regime of idle running (section 1 in Fig. 1);

II – acceleration of motor-vehicle with slippery clutch and put in I[st] gear up to the equalization of the angular velocities of crankshaft and clutch shaft (section 2 in Fig. 1);

III – acceleration of motor-vehicle at put in Ist gear at equalized angular velocities of crankshaft and clutch shaft

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(section 3 in Fig. 1);

IV – shifting II[nd] gear at clutch release (section 4 in Fig. 1);

V – acceleration of motor-vehicle with slippery clutch and put in IInd gear (section 5 in Fig. 1);

Results

The change of the engine angular velocity in the course of time at operation in a regime of idle running to the reach of magnitude $\dot{\varphi}_{d_0}$ at zero angular velocity of clutch is determined during the first stage. The first equation of system (3) at $M_r(t)=0$ is solved.

During the second stage the system (3) is solved up to the equalization of the angular velocities of crankshaft and clutch shaft $\dot{\varphi}_d = \dot{\varphi}_c$.

During the third stage is solved the first equation of system (3) at $M_r(t)=M_s(\dot{\varphi}_d)$, where $M_s(\dot{\varphi}_d)$ is the resistance moment caused by the external load supplied upon the engine shaft.

For the fourth stage the first two equations of the system (30 are solved at $M_r(t)=0$, while the system (3) at put in II[nd] gear is solved during the fifth stage.

The changes of the acceleration and the velocity of engine mass centre during the start from out-of-motion position up to the reach of a velocity chosen by the driver at put in II[nd] gear are represented in Fig. 1.

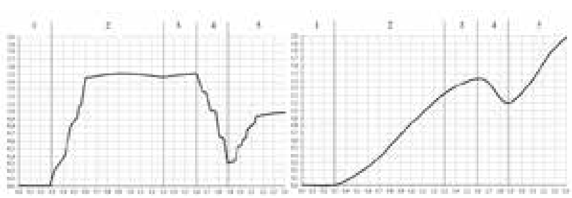

Fig. 1. Time dependence of the acceleration and the velocity of engine mass centre

The adequacy of the model is proved by the experimental data obtained for a motor-vehicle with close mass and technical characteristics placed at our disposal by Assoc. Prof. Nedelcho Ivanov, Ph D, who is a university teacher in Technical University in Varna (Fig. 2). The numerical experiments carried out are for a period corresponding to the period of the natural experiments up to 400 s.

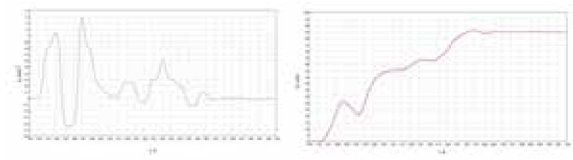

Fig. 2. Time dependence of the acceleration and of the velocity of engine mass centre

Conclusion

The experimental results show the practical applicability of the mechano-mathematical model for motor-vehicle acceleration during the start from out-of-motion position up to the reach of a settled operation at a certain gear. The procedure suggested is useful for the determination of a velocity and acceleration of a motor-vehicle during the drawing up of an auto-technical expertise, when the precision of the determination is of special meaning.

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