

$y_j^{(n)} > 0$  , if  $x_j > 0$ ;  $y_j^{(n)} < 0$  , if  $x_j < 0$ . It is also assumed that the j-th active source is oriented identically with the j-th arc. In this case  $y_j^{(a)}$  , in expression (1) is taken with a minus sign.

### References

1. Evdokimov A.G. Pipeline Transport Systems. Theory. Practical Applications. Mathematical Principles. - Kharkiv: Tochka Publishing House, 2004. - 572 p.

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### MODELING OF DYNAMIC VALUE CHARACTERISTICS OF DIESEL ENGINES

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*The article considers the issue of forming dynamic operating modes of a diesel engine during vehicle acceleration. The influence of turbocharger inertia on boost pressure, acceleration dynamics, and the occurrence of such phenomena as “turbo pit” and “turbo pick-up” is determined. The author proposes a method for mathematical modeling of transient engine operation based on the use of an extended mathematical model of the Blitz-PRO<sup>®</sup> turbo-piston engine. A system of equations for the dynamics of the engine, turbocharger, and pneumatic actuators is presented, which allows for highly accurate determination of changes in the speed, boost pressure, and load in real operating conditions. The results obtained contribute to increasing the accuracy of transient evaluation in modern diesel engines with gas turbine supercharging and can be used in the design improvement of supercharging systems.*

When a diesel internal combustion engine is used in a motor vehicle, transient operating modes constitute a significant portion of its operation. These modes include starting, warming up, accelerating, and braking. From the perspective of the turbocharging system's operation, the acceleration mode of the vehicle is of greatest interest [1]. Due to the inertia of the turbocharger, it takes a certain amount of time for its rotor to spin up to its operating speed. Consequently, during the initial acceleration phase, the boost pressure does not correspond to that during steady-state engine operation. To maintain the maximum permissible excess air coefficient, it is necessary to limit the cyclic dose of fuel injected into the cylinder, which leads to a decrease in engine power and an increase in acceleration time. This phenomenon is known as "turbo lag". As the vehicle accelerates, the boost pressure begins to increase sharply, which leads to a sudden increase in engine power and acceleration of the vehicle - "turbo lag". Both of these phenomena are unfavorable and are the subject of constant efforts by designers to eliminate them.

Fig. 1 shows the combination of external speed characteristics of the engine (VSH) and the resistance power (load) on the engine.

When accelerating a vehicle at maximum acceleration, the engine operates according to its external speed characteristic, despite the engine load being significantly lower than the power it generates. The difference between the engine's generated power and the load power is expended to increase the kinetic energy of the engine and vehicle. Clearly, the dynamic VSH is lower than the static VSH, which adversely affects the transition time.

The problem of favorable formation of dynamic VSH becomes more acute with increasing boost pressure, since, with single-stage boost, it becomes necessary to use high-pressure turbocompressors, which have higher rotor moments of inertia.

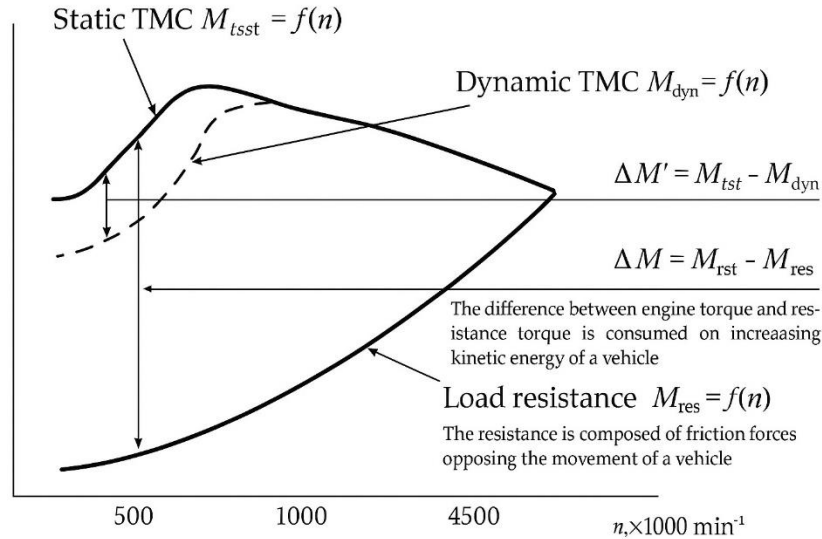


Fig. 1 External speed characteristics during vehicle acceleration and a fixed transmission gear ratio

To simulate transient operating modes, the Blitz-PRO<sup>®</sup> mathematical model of the turbopiston engine, developed at the Department of Tractors and Agricultural Machinery, Operation and Technical Service, was supplemented with the corresponding calculation modules. Initially, the steady-state operating mode of the engine is calculated before the onset of a transient process (e.g., acceleration). This step is necessary for the initial filling of the arrays of parameters of the working fluid in the engine cylinder, intake receiver, and exhaust manifolds [2 - 5]. Next, the sequence of engine operating cycles is calculated. In this case, the change in the rotational speed of the engine and turbochargers is calculated at a time interval corresponding to the cycle time. Dynamic equations are used for the calculation engine and turbochargers, as well as an equation for determining the load on engine:

$$\Delta n^{i-1} = \frac{60}{I_{eng}} \frac{N_e^i - N_{mp}^i - N_{load}^i}{x \left( \frac{\pi}{30} n^i \right)^2};$$

$$\Delta n_{TK}^{i+1} = \frac{60}{I_{TK}} \frac{N_t^i - N_K^i}{x \left( \frac{\pi}{30} n_{TK}^i \right)^2};$$

$$N_{load}^i = A_0 + A_1 \left( \frac{n^i}{n_H} \right) + A_2 \left( \frac{n^i}{n_H} \right)^2,$$

where  $n$  - is the current engine speed;  $n_{TK}$  - is the current engine speed turbocharger rotor;  $N_e$  - the current value of the effective engine power, which is the difference between the indicated power and power of mechanical losses;  $N_{load}$  - current value of engine load;  $N_t$  - instantaneous value of turbocharger turbine power;  $N_K$  - instantaneous value of turbocharger compressor power;  $I_{eng}$  - instantaneous value of power losses in transmission;  $I_{eng}$  - total moment of inertia of moving parts of engine, transmission and vehicle propeller;  $A_0, A_1, A_2$  - constant coefficients;  $I_{TK}$  - moment of inertia of turbocharger rotor;  $n_H$  - rated engine speed;  $N_e$  - rated engine power;  $i$  - time layer number.

The turbocharger dynamics equation is solved together with the iterative refinement of the pressure increase ratio in  $\Pi_K$  the turbocharger compressor based on the interpolation of the digitalized characteristics of the turbocharger.

It is especially important to emphasize the need to use extrapolated characteristics of the compressor and turbine of the turbocharger [6, 7] to ensure the stability of such a calculation, since the engine operates over a very wide range.

It should be noted that when simulating transient engine conditions, the mathematical model is also supplemented by a calculation of the dynamics of pneumatic actuators to determine the current flow area of the bypass valves [8, 9]. According to the fundamental law of dynamics:

$$\sum \bar{F} = -m \bar{a}; \bar{P}_s + \bar{P}_t + \bar{F}_{np} = -m_{mex} \frac{d^2 h_{cl}}{dt^2};$$

$$P_s = \frac{\pi d_M^2}{4} (p_s - p_o);$$

$$P_t = p_t \frac{\pi d_{BP}^2}{4} - p_{3T} \frac{\pi d_{cl}^2}{4};$$

$$F_{\text{np}} = C_{\text{np}} h_{\text{кл}} + B_{\text{in}},$$

where  $p_s$  - is the air pressure in the engine receiver;  $p_o$  - is the ambient pressure;  $p_t$  - is the gas pressure before the turbine;  $p_{3T}$  - is the gas pressure after the turbine;  $C_{\text{np}}$  - is the spring stiffness coefficient;  $B_{\text{in}}$  - is the static force of the spring;  $d_M$  - the diameter of the actuator membrane;  $d_{BP}$  - is the diameter of the bypass valve;  $d_{cl}$  - the diameter of the actuator membrane;  $h_{cl}$  - is the valve lift height;  $h_{cl}$  - the total mass of the moving parts of the mechanism.

In conclusion, it should be said that the application of the indicated approach to modeling the dynamic VSH [10] of diesel engines allows us to estimate transient processes in modern gas turbine supercharging systems with a fairly high degree of accuracy.

### References

- [1] Yu. L. Moshentsev, D. S. Minchev, A. V. Nagorny, and S. Dyakonov, "Extrapolation of experimental characteristics of centrifugal compressors," *Proceedings of the National University of Shipbuilding*, no. 4, pp. 57–63, 2011.
- [2] O. Lymar and D. Marchenko, "Prospects for the Application of Restoring Electric Arc Coatings in the Repair of Machines and Mechanisms," in *Proceedings of the 2022 IEEE 4th International Conference on Modern Electrical and Energy Systems (MEES 2022)*, 2022. doi: 10.1109/MEES58014.2022.10005709.
- [3] Yu. L. Moshentsev, D. S. Minchev, A. V. Nagorny, and A. S. Dyakonov, "Application of centrifugal compressor characteristics in numerical modeling of combined internal combustion engines," *Electronic Bulletin of the National University of Shipbuilding*, no. 5, pp. 33–38, 2011.
- [4] J. B. Heywood, *Internal Combustion Engine Fundamentals*, 2nd ed. New York: McGraw-Hill Education, 2018.
- [5] D. Marchenko, K. Matvyeyeva, and V. Kurepin, "Increasing the wear resistance of plunger pairs of high-pressure fuel pumps using extreme pressure additives," *Problems of Tribology*, vol. 29, no. 4(114), pp. 24–31, 2024. doi: 10.31891/2079-1372-2024-114-4-24-31.
- [6] R. Stone, *Introduction to Internal Combustion Engines*, 4th ed. London: Palgrave Macmillan, 2012.
- [7] V. Ganesan, *Internal Combustion Engines*, 3rd ed. New Delhi: McGraw-Hill Education, 2011.
- [8] Y. Kononov and O. Lymar, "Investigating the stability of oscillations of rectangular plates in an infinitely long rectangular parallelepiped with an ideal fluid," *Eastern-European Journal of Enterprise Technologies*, vol. 1, no. 7(133), pp. 14–21, 2025. doi: 10.15587/1729-4061.2025.323200.
- [9] R. J. Watson and M. A. Milovanovic, "Modelling turbocharged diesel engine transient performance," *International Journal of Vehicle Design*, vol. 19, no. 3, pp. 272–288, 1998.
- [10] P. J. Wallace and P. S. Leach, "Simulation of turbocharger dynamics and transient performance in diesel engines," *SAE Technical Paper 2000-01-0919*, 2000.

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### BLOCKCHAIN-ENABLED MATHEMATICAL MODELLING OF URBAN PASSENGER TRANSPORT

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*Annotation. This paper proposes a mathematically grounded framework for organising urban passenger transport that couples classic transit modelling (assignment, headway control and capacity analysis) with a permissioned blockchain for trusted, auditable data exchange among agencies, operators and users. We formalise the problem as minimising generalised passenger time and operational cost subject to fleet, capacity and service constraints, while enforcing the integrity of ticketing, vehicle*