The results of modeling and evaluating the dynamics of a road train with an active trailer link based on valve-inductor electric machines

A N Sova¹, G S Mazlumyan¹, O V Egorov¹, S A Eruslankin¹, S S Shadrin¹ and V A Sova²

¹Moscow Automobile and Road State Technical University (MADI), 64, Leningradsky ave., Moscow, 125319, Russia
²Bauman Moscow State Technical University, b. 1, 5, Baumanskaya 2-a str., Moscow, 105005, Russia

E-mail: slsova@mail.ru

Abstract. The article describes the results of modeling and evaluating the dynamics of a road train with an active trailer link based on valve-inductor electric machines. It gives a general view and an equivalent road train diagram, shows a generalized simulation model of the movement of a two-link road train developed in the Simulink environment for studying motion in various road conditions. We proposed a reference surface model based on the terrain map, blocks were developed for calculating the road tilt angles separately for the tractor and the semitrailer, taking into account the type of coating under each road train wheel at the current time. The visualization of the movement of the road train is shown, the results of modeling and evaluation of the dynamics of the road train with an active trailer link based on valve-induction electric machines for creating control systems for individual drives of the electric motor-wheel of an active semi-trailer and developing a program and methodology of full-scale experimental research representations.

The object of research is a special vehicle (Fig. 1), which is a two-link road train consisting of a four-axle truck tractor based on a wheeled tractor equipped with a hydromechanical transmission, and a four-axle active semi-trailer with controlled motor wheels equipped with an electromechanical transmission based on valve-induction electric drives. All wheels of a two-link truck train are swivel.

Figure 1. General view of a two-link road train with an active trailed link based on valve-inductor electric machines
When individually controlling the traction forces of the active wheels of the semitrailer, the initial was the calculated external characteristic of the valve-inductor electric drive, reduced to the wheel propulsion, shown in Fig. 2.

![Figure 2. External characteristic of a valve-inductor drive, reduced to a wheel propeller](image)

For calculations, the external characteristic of the valve-inductor electric drive was used, the gear ratio of the gearbox installed between the valve-inductor electric drive and the wheel mover was 34.85 and the gearbox efficiency was 0.944. In order to simplify the mathematical model and reduce the calculation time, we will use the equivalent circuit of the research object presented in Fig. 3.

![Figure 3. Equivalent circuit of a two-link road train with an active trailed link based on valve-inductor electric machines](image)

The developed mathematical model of the motion of a two-link road train with an active trailer link based on valve-induction electric machines has 30 degrees of freedom (6 degrees of freedom of the tractor body, 6 – of the body of the trailer, rotation of 6 wheels, 6 wheel turns, individual type of bearing surface under each of 6 wheels when driving).

The modularity of the constructed Simulink model allows us to move from the equivalent circuit of the research object to the actual one for the next step to refine the control algorithms of the valve-inductor drive.

The developed mathematical model can be used in the educational process in the preparation of specialists in specialized specialties [8].

Figure 4 shows a generalized simulation model of the movement of a two-link road train of the equivalent circuit developed in the Simulink environment.

To simulate the movement of a two-link road train with an active trailed link based on valve-inductor electric machines in various road conditions, the terrain map was set separately in a mathematical model, an example of which is shown in Fig. 5.
Figure 4. Simulink model of a two-link road train
Thus, the model specified the longitudinal and transverse slopes of the supporting surface, as well as segments of the following types of coatings with individual adhesion characteristics [1]:

- dry asphalt;
- wet asphalt;
- dry concrete;
- dry gravel;
- wet gravel;
- snow;
- ice.

Each of the 7 types of supporting coatings corresponded to individual rolling resistance coefficients of the wheel propulsors [2].

Fig. 6 shows a block that calculates the slope angles of the road separately for the tractor and semitrailer and determines the type of supporting coating under each wheel of the road train at the current time. In addition, a code was developed for the visualization program for the movement of a road train with an active trailer link based on valve-induction electric machines.

An example of graphical visualization of the movement of a road train (equivalent circuit) along a circular path is shown in Fig. 7.

The results of simulation and assessment of the dynamics of the movement of a road train with an active trailer link based on valve-induction electric machines when applying constant torques of 9500 N·m to the wheels of the front axle of the tractor and sinusoidal action on the steering wheel on a flat horizontal surface with dry asphalt coating are presented in Fig. 8–21.

The developed simulation mathematical model of the movement of a two-link road train with an active trailed link based on valve-inductor electric machines includes:

1) a mathematical model of the movement of a tractor of a two-link road train with an active trailed link in the environment of MatLab Simulink;

2) a mathematical model of the movement of a two-link road train with an active trailed link based on valve-inductor electric machines in a MatLab Simulink environment;

3) a mathematical model of a virtual experimental site in the environment of MatLab Simulink for experimental research and testing of a two-link road train with an active trailed link based on valve-inductor electric machines.
**Figure 6.** Block for calculating the current slopes of the road and determining the type of supporting coating under each wheel of the road train

**Figure 7.** Visualization of the movement of a two-link road train with an active trailed link based on valve-induction electric machines
Figure 8. Wheel angle and hitch angle

Figure 9. Road train speed

Figure 10. Acceleration of the center of mass of the tractor
Figure 11. Acceleration of the center of mass of the semi-trailer

Figure 12. Angular speeds of the tractor and semitrailer

Figure 13. Wheel speeds
Figure 14. Angles

Figure 15. Longitudinal reactions of the tractor

Figure 16. Lateral reactions of the tractor
Figure 17. Vertical tractor reactions

Figure 18. Semi-trailer longitudinal reactions

Figure 19. Side reactions of the semi-trailer
The performed simulation of the curvilinear motion of a two-link road train with an active trailed link based on valve-inductor electric machines made it possible to justify and develop:

- a control system for an individual drive of an electric motor-wheels of an active semi-trailer;
- the program and methodology of full-scale experimental research.

Field experiments, pilot testing and testing of a two-link road train with an active trailed link based on valve-inductor electric machines made it possible to verify the adequacy of the simulation model and make the necessary refinements, as well as confirm the improvement of the technical and operational properties of the research object using the developed control system.

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