Ensuring the safety of operation of the truck with the semi-trailer

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Abstract. This article raises an important issue of road train stability under various operating conditions, it also discusses one of the elements of active safety in the operation of road trains consisting of a truck tractor and a semi-trailer, namely the ordering of the mutual position of the parts of the train. A brief overview of the principle of operation of various schemes designed to prevent the folding of a tractor with a semi-trailer, as well as structural and functional capabilities, some disadvantages and advantages is given. The new and one of the latest implementation systems for blocking the folding of a trackless vehicle consisting of a semi-trailer is presented. The blocking mechanism for folding a train includes a closed kinematic chain using flexible coupling, as well as a controlled closed hydraulic system. There are certain promising possibilities of this proposed technical solution in terms of increasing active safety in the operation of the trailer and organizing the provision of controllability of the saddle tractor relative to the semi-trailer interconnected with the steering and steering wheels, with the position of the brake pedal sensor road trains, with driver’s actions, weather conditions and traffic situations.

1. Introduction

A modern car, especially if it is a truck and a road train, which is essentially a railless vehicle and a complex technical device [1], is still a source of increased danger. With the social significance, as well as the potential danger during operation, the car is equipped with tools and systems that contribute to its safe operation, while creating elements of both active and passive safety [2]. Active safety involves a set of constructive and operational properties of the car, aimed at preventing a traffic accident and at eliminating the prerequisites for their occurrence. It is associated with the design features and systems of the car, which help to prevent its accident. Passive vehicle safety is aimed at reducing or completely preventing the harmful effects on a person after a car accident. As practice shows, a car under the direct control of a driver - a person, in bad weather and road conditions can get into a traffic accident. This often leads to damage to the car or its destruction. Rarely, when a driver, even if he is a professional, can promptly and correctly respond to the prevailing conditions and get away from such an event as an accident of a car - a road train, accompanied by its folding. In a traffic accident, in addition to the car itself, other cars, people, nearby road and communications infrastructure may be affected.

The phenomenon of folding trailer, as a rule, is the result of the loss of their course stability and the stability of the links in the system of an articulated vehicle as it moves. The course stability is initially
determined [3-5] by the given position of the steered wheels, which determines the position of the tractor unit itself relative to the semi-trailer. The folding of a road train arises for various reasons, the most common of them being the difference in the braking forces applied to the wheels of the tractor and the road train; a different coefficient of adhesion of the pavement both along the sides of a road train and those falling on its part; adverse weather conditions accompanied by a decrease in adhesion to the roadway (rain, snow, ice). Adequate interaction through the articulation of the links of the road train also affects the course stability, it is determined by controlling the position of the truck tractor relative to the semi-trailer. The direction of movement of the train is influenced not only by the position of the managers on the road surface with a high coefficient of friction, the wheels of the truck tractor, but also by the continuity and operability of both themselves and the systems associated with them (for example, tire rush or bearing sticking wheel hubs, etc.), as well as conditions for creating a situation of a traffic accident.

2. Research Overview
There are various schemes for the implementation of blocking folding trucks. Some of them [6] are relatively compact in design, since all the elements are located almost above the saddle of the tractor, but they are also quite complex, since they include hinged-reference mates, having a limited service life. Moreover, a part of the structure occupies the space of the semi-trailer, which may affect the performance of the train. Others [7] have hidden elements under the semi-trailer frame, which improves the performance characteristics of the car, but only works in the deceleration braking mode (when fixing the flexible element), in addition, which does not provide the possibility of correcting the situation when the folding of the tractor and semi-trailer has already happened. Some of them allow one [8] to block the movement of the semi-trailer when reversing, which eliminates the folding of the train or provide [9] regulation of the brake pressure in the wheels of the semi-trailer, which prevents folding, correcting the position of the semi-trailer relative to the tractor when the energy of the compressed air is supplied from the pneumatic system of the car brakes. There is a system for implementing the blocking of folding of a train [10], the solution of which is to increase the reliability and safety of operation of a train in a vehicle with a semi-trailer in wider operating conditions.

3. Result and discussion
Let us consider that the system for blocking the folding of a train [11] provides for the smallest number of power elements, respectively, the total weight of the system due to its simplification is reduced. The system for locking the folding of the road train (figure 1) consists of: a tractor unit 1 connected to the semi-trailer 2 via a free kinematic connection of the coupling device 3 with the pin 4 of the semi-trailer 2. To control the position of the truck tractor 1 relative to the axis of the pin 4 of the semi-trailer 2, the existing kinematic connection is equipped with a blocking mechanism for folding a trailer train associated with an automatic control system. The blocking mechanism for folding a train includes interconnected closed hydraulic system and a kinematic chain. The hydraulic system consists of a hydraulic cylinder 5 with blocks at the ends, fixed along one of the sides of the semi-trailer 2 parallel to the longitudinal axis; the rod cavities of the hydraulic cylinder 5 are interconnected by a pipeline 6. On the pipeline 6 connecting the rod cavities of the hydraulic cylinder 5, an electromagnetic valve 7 connected to the electronic control unit of the car 8 is installed. At the same time, one hydraulic cylinder 5 is used with a practically built-in pipeline connecting the rod cavities of the hydraulic cylinder 5, which is equipped with an electromagnetic valve 7 controlling the state of the hydraulic cylinder. The kinematic chain is built on the flexible connection of the metal rope 9. At the ends of the metal rope 9 there are loop-shaped terminations that are connected through special supports of blocks 10 and 11 with fastening heads 12 and 13 of the rod 14 of the hydraulic cylinder 5. The supports of blocks 10 and 11 allow the tension of the metal rope 9 at installation and adjustment the blocking mechanism of folding of the road train. Metallic rope 9 is passed through the intermediate support 15, the guide disc 16 pivotally mounted on the pin 4 of the semi-trailer 2 and having the possibility of fixation against rotation relative to the coupling device 3 of the tractor 1. This can be achieved either by fixing the guide disc 16 to the front of
the saddle when the help of the bracket-earring 17, after docking the semi-trailer with the tractor unit, or the presence in the design of the guide disc 16 of the trunnion 18, which is into the groove 19 of the fifth-wheel coupling device 3 when docking the semi-trailer with tractor 1.

Figure 1. The conditional scheme of the device blocking folding trucks: SS – shock sensor; ABS – anti blocking system; ECUA – electronic control unit of the vehicle; SWPS – steering wheel position sensor; BPPS – brake part position sensor.

Figure 2. The conventional scheme of the device blocking folding and ensure controllability of the train: SS – shock sensor; ABS – anti blocking system; ECUA – electronic control unit of the vehicle; SWPS – steering wheel position sensor; BPPS – brake part position sensor.

The operation of the system is as follows. When the tractor 1 rotates relative to the semi-trailer 2, for example, to the left, there is an impact of the kinematic chain on the hydraulic cylinder 5, which leads to the movement of the rod 14 and the piston of the hydraulic cylinder 5 in the direction of the tractor 1. When this occurs, the displacement of a fluid from one rod end of the hydraulic cylinder 5 and the flow of it to another, realizing the relatively free interaction of rod and head ends of the cavities in a closed hydraulic system. The stroke of the piston of the hydraulic cylinder 5 is carried out in such a way as to provide the maximum permissible angle of rotation of the semitrailer 2 relative to the tractor 1, which is necessary for satisfactory maneuverability of the road train and for its turn. For the safety of the road train in different conditions, it is necessary to block the position of the semi-trailer 2 from turning relative to the tractor 1 in a horizontal plane relative to the axis of the pivot 4. When the driver is selected or the automatic blocking of the road train, carried out both when it is moving and when it is stopped, an obstacle is created to the rotation of the tractor 1 relative to the semi-trailer 2. This condition precedes the signal to the solenoid valve 7, which changes the flow section of the pipeline 6 until it is completely...
closed. The blocked hydraulic cylinder 5 due to the immobility of the piston and rod through the metal rope 9 prevents the rotation of the semitrailer 2 relative to the tractor 1, preventing the folding of the road train. Thus, the task of fixing the position of the tractor 1 relative to the semitrailer 2 connected to the tractor through the coupling device 3 is realized, which ensures the mobility of the coupling both in the vertical and horizontal planes. The solenoid valve 7 at normal movement of the road train is normally open, and if necessary, the lock is in a predetermined position, preventing the flow of fluid in the hydraulic system. It is possible the manual permanent forced locking of the driver from the instrument panel on the driver a special key “block trains”. For automatic control of the system and of the electromagnetic valve 7, its connection with the electronic control unit of the car 8 is provided, in which a certain type of signal is formed: constant or by the signals of the sensors included in the electronic control unit of the car 8. To generate the output signal from the electronic control unit of the car 8, information is supplied to its input: about the actions of the driver through the brake pedal position sensor 20 and the steering wheel position sensor 21, as well as the state of the roadway from the anti-lock and anti-slip systems 22. In addition to these interrelated elements of control of the state of the system, a shock sensor 23 is provided to increase the efficiency of its operation, giving a signal to the electronic control unit of the car 8 about the collision of the car both in the parking lot and when it is moving.

To increase the controllability of the road train by completing the elements (figure 2), allowing to control the angle of position of the parts of the road train, the above system of blocking the folding of the road train turns into a system of blocking the folding and ensuring the controllability of the road train. Its non-closed hydraulic system, to which, if necessary, energy is supplied, is filled with special oil, contains electromagnetic valves 24, 25, 26 – two three-way and one double two-way normally closed controlled automatically through the electronic control unit of the car 8. Alternatively, the hydraulic system is connected via pipelines to an external hydraulic system, such as the steering of a tractor unit; a semi-trailer position sensor relative to the tractor unit, electrically connected to the electronic control unit of the vehicle and mechanically to its parts. The system of blocking the folding and ensuring the controllability of the truck tractor 1 connected to the semi-trailer 2 through a free kinematic connection of the saddle-coupling device 3 with the pivot 4 of the semi-trailer contains to control the position of the tractor 1 relative to the axis of the pivot 4 of the semi-trailer the available kinematic connection is additionally equipped with a mechanism for blocking the folding and ensuring the controllability of the road train with an automatic control system. The mechanism of blocking the folding and ensuring the controllability of the road train includes an interconnected hydraulic system and a kinematic chain. Actions to ensure the controllability of the road train, notably, for the organization of a variable controlled power connection between the tractor 1 and the semi-trailer 2, occur through the hydraulic cylinder 5, which operates with the closed solenoid valve 7. When controlling the solenoid valves 24, 25, 26 through the electronic control unit of the car 8, pressure is applied to the necessary rod ends of the hydraulic cylinder 5 to move the piston with the rod 14. The valve 26 allows communication with the external hydraulic system for supplying energy to the hydraulic system of the folding locking mechanism and ensuring the controllability of the road train, for example, the hydraulic steering of the tractor 1 if it is necessary to activate the "precision steering" process and the angular movement of the tractor relative to the semi-trailer. When the solenoid valve 7 is open and the valve 26 is closed, the oil flows freely between the rod ends of the hydraulic cylinder 5. In accordance with the work algorithm of the process of "steering", programmed in the electronic control unit of the vehicle 8, system provides for the installation of the sensor 27 of the position of the trailer relative to the tractor, connected electrically with the electronic control unit of the vehicle and its mechanical parts. In the operation of the road train, the driver's actions and actual road conditions in the electronic control unit of the car 8 are analyzed by signals from the anti-lock system 22 by its speed sensors of the car wheels, from the car sensors: 20 brake pedal positions, 21 steering wheel positions and 23 impacts. As a result of this analysis, according to the implementation of the working algorithm, taking into account the signal from the sensor 27 of the position of the semi-trailer relative to the tractor, the corresponding generation of control signals to the electromagnetic valves 7, 24, 25, 26 and the impact of the system on the car. While the
driver controls the vehicle (until the autopilot option with the appropriate navigation, telemetry and tracking system is activated), the driver sets the position of the vehicle by operating the steering wheel with which the steering wheel position sensor is connected. In the long parking lot, the driver has the ability to block the road train manually. The steering wheel acts on the power steering, which parts of the steering mechanism in turn are associated with the control wheels of the tractor. At the same time, the power steering is in no way directly connected with the proposed device of the folding blocking system and ensuring the controllability of the road train, but the device, for example, can use the energy of the same hydraulic pump of the power steering, which is in a permanent drive on a running internal combustion engine mounted on the chassis, in this case on a tractor. The electronic control unit of the car when driving: monitors the signals from the sensors, determines the road conditions, evaluates the actions of the driver; when analyzing the signals from the steering wheel sensors and the position of the parts of the road train, the comparison is carried out – determines the compliance of the signals or its deviation, characterizing the current state of the steering wheel and the parts of the road train, if necessary (to maintain compliance of the matched signals with each other) in accordance with the algorithm, delivers control signals to the electromagnetic valves to give an appropriate mutual position of the parts of the road train to the given position of the steering wheel; sends a signal to the solenoid valves in an extreme case, associated with the presence of a road train impact, on the signal from the appropriate sensor. The electronic control unit of the car gives a signal to the solenoid valves in an extreme case (with a possible sound notification of the driver about the creation of an emergency): associated with the presence of an impact when the car is parked, on the signal from the appropriate sensor, in the absence of blocking the road train (for example, at a traffic light); associated with the sharp actions of the driver (sudden braking, sharp movement of the steering wheel with a significant impact on the stability of the road train, speed).

Driving a car through an intelligent system can create the opinion that the car will be like an unguided shell, but intelligent control systems are always before practical use are long debugging, taking into account many options and combinations of external conditions, while providing more and duplicate control algorithms for adequate action, which is worthy of a separate technical solution.

4. Conclusions
It can be noted that there are different ways of implementing safety in relation to a non-rail vehicle, in the form of a road train with a truck tractor at the head, have their disadvantages and advantages. At the same time, there is no possibility of orderly and interrelated control of the position of the components of the road train to maintain the stability of the course. To improve passive and active safety of the vehicle, a system of blocking the folding of the road train, controlled through the electronic control unit of the car, is proposed, taking into account the position of steering wheel, brake pedals, the speed of the road train, the driver's actions, weather conditions and the road situation [12, 13]. In order to increase the controllability of the road train by completing the elements that allow to control the angle of the position of the parts of the road train, it is possible to improve the above system of blocking the folding of the road train and convert it into a system of blocking the folding and ensuring the controllability of the road train, which, among other things, takes into account the mutual position of the parts of the road train in its functioning.

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