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ANALYSIS OF EXISTING CONSTRUCTIONS OF ROAD TRAINS WITH ACTIVE TRAILERS

The role of road transport in logistics transportation is determined and peculiarity of logistics transportation which performs by military formations is shown, namely a wider range of changes in operating conditions. Attention is drawn to the fact that both single trucks and road trains are mostly used for road transportation. The advantages of using road trains in comparison with single automobiles during performing transportations are noted. It is shown that in the modern automotive industry the field connected with the use of multi-axle heavy-duty road trains and articulated self-propelled platforms actively develops. Widespread and further improvement of these vehicles is due to a large number of objective factors.

Contradictions between the existing constructions of road trains and the requirements for the efficiency of automobile transportations especially military have been established. One of the field of efficiency increase of automobile transportations using road trains with active trailer links is specified. The existing constructions of road trains with active trailer links are analyzed. Features of a construction, advantages and disadvantages of active links of road trains of various types of energy transfer are defined. The efficiency of various drive system transmissions of active axles of trailer links, namely: mechanical, hydrostatic and electrical to achieve maximum passability and dynamism in a wide range of operating conditions of road trains.

It is substantiated that the most promising is the use of electrical (or electromechanical) drive on the wheels of trailer links of the road train which will simplify the construction of the transmission and futher increase the passability and dynamism of the road train by separate control of individual wheels.

Keywords: road train, active trailer, transmission, trailer link, passability.

INTRODUCTION

Road transport is one of the main types of transport which is used to perform tasks of logistics transportation by both military formations and civilian organizations. Both single trucks and road trains are mostly used for road transportation.

In the modern automotive industry, the field connected with the use of multi-axle heavy-duty road trains and articulated self-propelled platforms is actively developing. Widespread and further improvement of these means of transport is due to a number of objective factors: the need for transportation of heavy bulk cargo with the exception of the processes of separate transportation and further assembly of components; the need to increase load capacity at the same time ensuring high passability when driving on dirt roads and off-road; the need to provide low pressure on the supporting surface in order to reduce the destructive impact on the soil, etc. [1].

The use of road trains in industrial and agricultural areas with a developed road network has great prospects. But the need to use road trains in a wide range of road operating conditions, namely, in off-road conditions, which is typical for military wheeled vehicles, becomes especially relevant. However, the existing constructions of the drive wheels of road trains do not fully provide high passability and dynamism, which is important in terms of ensuring their survivability in military operation [1].

ANALYSIS OF LITERATURE SOURCES AND PROBLEM STATEMENT

Analysis [2-5] showed that the support and coupling properties of road trains are much lower than those of single automobiles. Various constructive solutions are known to increase the traction and dynamic properties of road trains. The desire to increase the passability of road trains has led to the creation of so-called active road trains. Road trains with a drive on the wheels of a trailer or semi-trailer are called active trailer links. Their main difference is the distribution of engine power not only on the wheels of the tractor, but also on the wheels of the trailers [6]. To increase the passability of road trains (especially large capacity) the drive wheels of trailers and semi-trailers use [5].

Thus, the activation of the wheels of the trailer (semi-trailer) not only improves the passability and dynamism of the road train compared to a single automobile but even surpasses them and at the same time ensure the transportation of greater mass goods. In scientific papers [2-5] the classification of road trains, their layout schemes, and constructive features that are characteristic of passive trailer links are given. But the issues of construction of road trains with active trailer links and features of torque transmission to the driving wheels of the trailer (semi-trailer) are not considered.

The drive of active towing links can be constant and periodic action. Drives of constant action have rather small distribution and are applied mainly on heavy-duty multilink road trains. On two-link road trains, drives of periodic action (booster type) are usually used. According to the transmission type of the drive system of the active axles trailer links are divided into mechanical, hydrostatic and electrical [6]. Features of construction, advantages and disadvantages of these active links of different types road trains of energy transfer need to be researched.

THE AIM AND OBJECTIVES OF THE STUDY

The purpose of the study is to determine the options of rational use of different types of energy transfer to the driving wheels of a trailer or semi-trailer on the basis of a comparative analysis of the constructions of active road trains.

To achieve this aim it is necessary to solve the following objectives:

- to carry out the comparative analysis of active links schemes of road trains with the drive of driving wheels of the trailer or the semi-trailer;
- to determine the most effective type of wheel drive system of a trailer link of road trains.

RESULTS OF THE STUDY

The experience of creating active trains shows that in domestic practice they are developed mostly with semi-trailers and foreign experts prefer trailers. But two constructive schemes of a mechanical drive of wheels of the trailer (semi-trailer) of a road train are possible: with transfer of a twisting moment by usual cardan transfer and through a pin of the truck-coupling device. A significant disadvantage of the first scheme is the limitation of the folding angle between the tractor and the semi-trailer by the maximum allowable angles of the cardan joints (up to 45 °) which significantly impairs the maneuverability.

For the improvement of the maneuverability of road trains with the transfer of torque to the cardan drive, the British company Multidrive uses a coupling device with a double articulation mechanism [7]. To eliminate the need of cardan transmission work on critical angles the rotary table of a back cart of the semi-trailer is entered. This coupling device provides increased angles of longitudinal (up to ± 15 °), transverse (up to ± 10 °) and horizontal (up to ± 100 °) flexibility. As the experience of Multidrive shows, this type of drive is the most rational for road trains with 8 × 8 wheel formula. The disadvantage of this scheme is the vulnerability of the drive elements of the trailer link during driving on cross-country, as well as the complexity of the operations of coupling and uncoupling. The layout of the active road train with the wheel formula 8 × 8 with a mechanical drive is presented in Fig. 1.

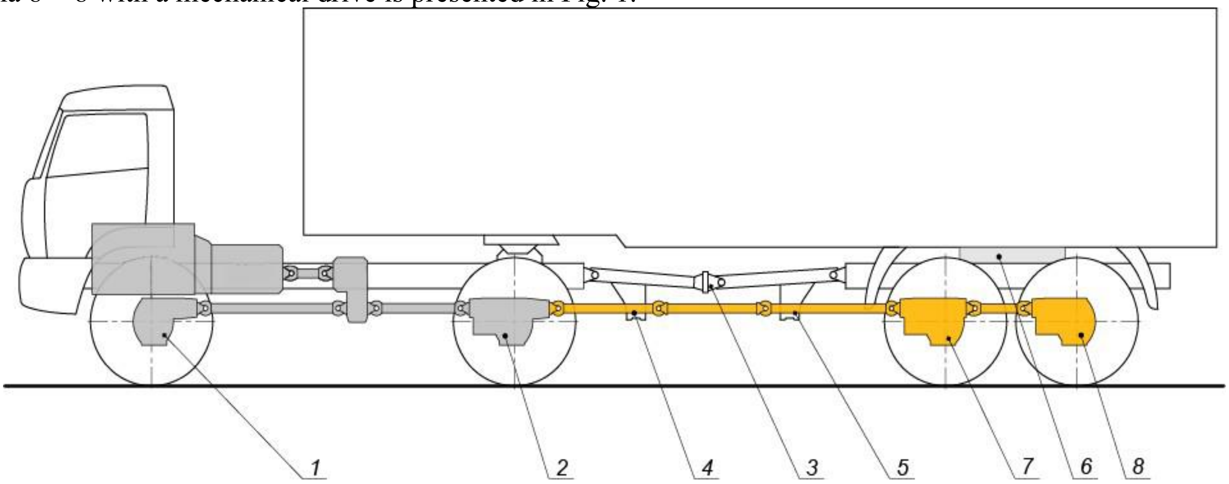

Fig. 1 - Layout of drive units of the "Multidrive" type: 1, 2, - driving axles of the tractor; 3 - the mechanism of articulation; 4, 5, - intermediate supports; 6 - rotary mechanism; 7, 8 - leading axles of the semi-trailer

The basis of most existing constructions of road trains was the mechanical drive of the drive wheels of semi-trailers from the transmission of tractors that towed them [4]. After testing a number of experimental constructions, road trains with a 10x10 wheel formula, consisting of three-axle all-wheel drive tractors and active two-axle semi-trailers with all driving single-slope wheels were recognized as the most effective. The layout of the active road train (wheel formula 10 × 10) with a mechanical drive is presented in Fig. 2.

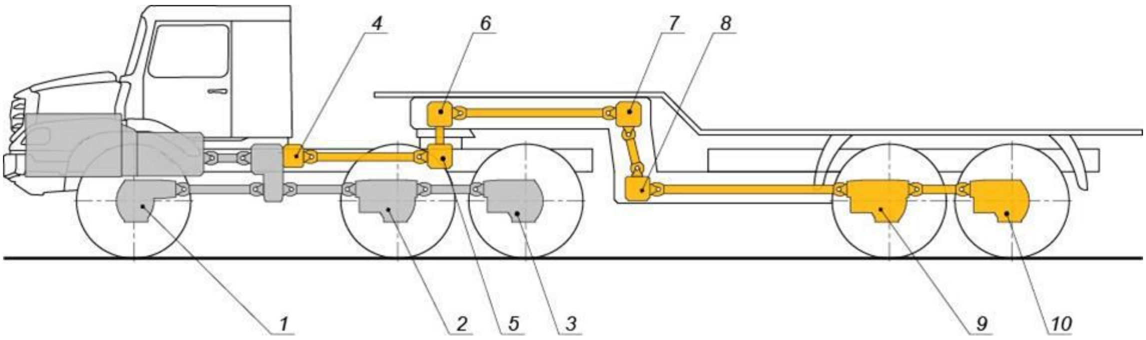

Fig. 2 - Layout of mechanical drive units of the semi-trailer: 1, 2, 3 - leading axles of the tractor; 4 - power take-off box; 5, 6, 7, 8 - angular reducers; 9, 10 - leading axles of the semi-trailer.

This type of drive has the following disadvantages:

• the use of a non-standard support-coupling device, which does not provide the possibility of uncoupling the links of the road train and replacing the trailer;

• a significant number of angular reducers and cardan shafts that increase the weight of the drive;

• kinematic discrepancies in the rotation of the wheels of the tractor and trailer and the problem of optimal redistribution of the required traction and braking forces on each wheel of the road train.

Recently a hydrostatic drive has been widely used to activate the wheels of trailers in the domestic and foreign automotive industry. For active road trains hydrostatic drive has the following advantages over mechanical [2, 5]:

• stability of work at low speeds and big loadings;

• convenience of arrangement of units of the drive;

• ease of obtaining a fast (≈0.12 s) and symmetrical in moments and kinematic parameters of the reverse drive, which allows to perform vigorous "rocking" of a stuck automobile, which is typical for operation in difficult road conditions;

• freedom of transmission units layout;

• rigid kinematic and power characteristics of the hydrostatic transmission, which is close to the characteristics of the mechanical continuously variable transmission and low inertia of the drive which makes it possible to control the gear ratio of the drive with high accuracy according to any given law;

• energy efficiency of the automobile with hydrostatic transmission during increase in number of its leading axes decreases less intensively than in automobiles with mechanical transmission;

• reliable protection against overloads (by means of safety valves and pressure limiters).

According to Sisu firm, a road train equipped with hydrostatic transmission develops traction 25% higher and overcomes the ascent 1.5 times steeper than without it [5].

Schemes of hydrostatic drives of active wheels of trailer links are divided into two main types: "hydraulic shaft" and "hydraulic motor-wheel". In such constructions, the hydrostatic drive performs the functions of cardan shafts, providing torque to the drive axles of the trailer link. The layout of the units of the drive type "hydraulic" is presented in Fig. 3

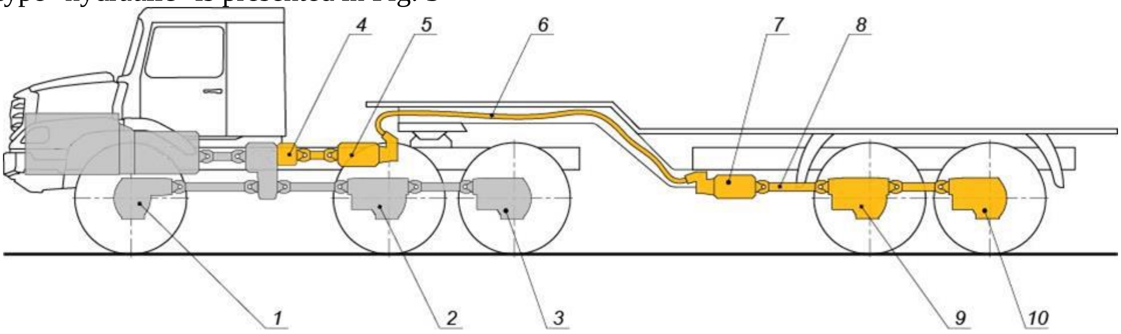

Fig. 3 - layout of units of the hydrostatic drive of the semi-trailer of the "hydraulic shaft" type: 1, 2, 3 - leading axles of the tractor; 4 - power take-off box; 5 - pump; 6 - flexible hoses; 7 - hydraulic motor; 8 - semi-trailer drive shaft; 9, 10 - leading axles of the semi-trailer.

The layout of the units of the hydrostatic drive of the semi-trailer of the "hydraulic motor-wheel" type is presented in Fig. 4.

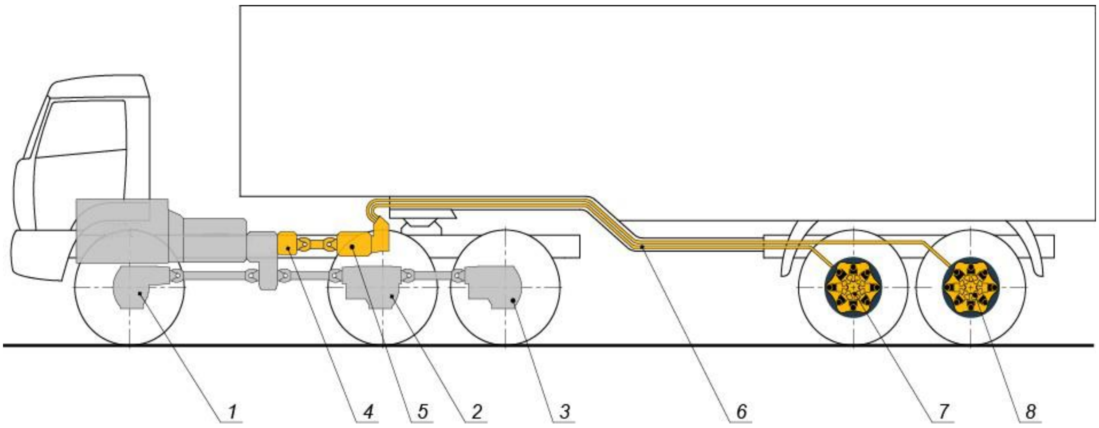

Fig. 4 - Layout of units of the hydrostatic drive of the semi-trailer of the type "hydromotor-wheel": 1, 2, 3 - leading axles of the tractor; 4 - power take-off box; 5 - pump; 6 - flexible hoses; 7, 8 - hydraulic motor.

A feature of this drive is the widespread use of standard units. However due to the small number of hydraulic units (one pump and one motor), a significant part of the drive is accounted for by mechanical units (main gears, differentials, cardan gears). In this layout, the possibility of blocking the wheel differentials in the axles of the trailer link of the road train should be realized to increase the passability [5].

At the present stage of technical development, the realization of the hydrostatic drive occurs according to the scheme of the type "hydraulic motor-wheel". In this case, the hydrostatic motor is built into each of the engines. The advantage of radial-piston hydraulic motors is the ability to transmit high torques and stable operation under load at low speeds (7 ... 10 min $^{-1}$) which simplifies the construction of the motor-wheel, as it eliminates the need for a wheel reducer. Axial-piston hydraulic motors have a smaller diameter than radial-piston, so they are used with a small diameter of the wheel hub. Under load the minimum stable speeds of such a hydraulic motor are in the range of 100 ... 150 min $^{-1}$, so the installation of a reduction gear is needed.

The peculiarity of the hydrostatic transmission is that it operates in a rather narrow range of speeds of the machine which is explained by the working processes of volumetric hydraulic machines [8].

The use of hydraulic drive is limited for the following reasons:

• efficiency is less than that of a mechanical drive (due to double energy conversion);

• the complexity of operation in low temperatures (to maintain efficiency it is necessary to constantly pump the working fluid, which leads to large bubbling losses);

• high cost compared to a mechanical drive; limited use in long-distance road trains (due to large losses in pipelines).

When creating multi-wheel drive automobiles(which include active road trains) the most rational is the use of electrical (electromechanical) transmission [9-14]. Electrical is a transmission in which the conversion of power flow factors of the drive motor of the machine in the entire control range is carried out by an electric torque transformer. The simplest transformer consists of two electric machines, one of which operates in generator mode and the other in electric motor mode. If in such transfer step (friction-gear) reducers or other mechanical distributing mechanisms are established it is called electromechanical. The main advantages of electromechanical transmission:

• •the characteristic of the traction electrical motor provides realization of stepless transfer of power on wheels and a possibility of movement at "creeping speeds";

• significantly reduces the number of mechanical elements of the transmission (there is no gearbox and transfer case, reduces the number of cardan shafts, etc.);

• ease of reversal;

• there is a possibility of individual distribution of power on wheeled engines according to external conditions in which they are.

To activate the wheels of a trailer or semi-trailer of a road train with a tractor that has a serial drive, an electric drive of periodic action is used, which is applies when driving in lower gears of the tractor gearbox. To reduce driving losses in higher gears, it is necessary to "break" the kinematic connection between the wheel and the links of the gearbox with the traction motor [7].

Electric transmissions with a permanent drive are used on all-wheel drive trains with a large number of drive axles. When driving in difficult road conditions or at full load all electric motor wheels realize the power transmitted from the power flow of the drive motor of the automobile and the generator, and the coupling properties of the train are fully used [7].

The layout of the units of the electrical drive of the semi-trailer is presented in Fig. 5 [7].

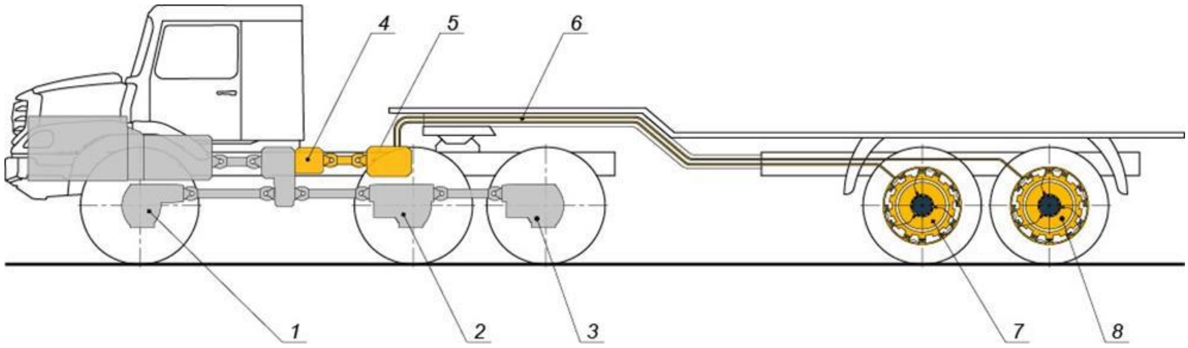

Fig. 5 Layout of electrical drive units of the semi-trailer: 1, 2, 3 - leading axles of the tractor; 4 - power take-off box; 5 - generator; 6 - power wires; 7, 8 - electrical motor-wheel.

During the movement of such road trains on roads with the improved covering and with incomplete loading the necessary force of traction of the automobile considerably decreases. In these conditions it is expedient to disconnect a part of the electrical motor wheels. Taking into account the modern development of science and technology, semi-trailers with electrical drive of semi-trailer wheels should be created for truck tractors with electromechanical transmission as the car already has a powerful generator and it is possible to use common (general) control algorithms for electromechanical transmission.

DISCUSSION OF RESULTS

The analysis shows that the further development and use of the mechanical drive of the leading wheels of the trailers is not effective because it leads to a significant complication of the train construction and increase energy costs (fuel consumption) for the movement of the automobile.

Hydrostatic type of drive is most often used in the construction of tractors and tractor trains. In constructin of automobeles it received limited use.

Therefore, in our opinion, the use of electrical drive (or electromechanical) on the wheels of the trailer links of the road train is promising which simplifies the construction of the transmission and in the future to increase the passability and dynamism of this automobile through separate control of individual wheels.

CONCLUSION

1. As a result of the study it was determined that the most promising is the use of electrical drive of the leading wheels of the trailer link of the road train.

2. The use of an electrical drive of a trailer or semi-trailer allows in the future to increase the passability and dynamism of the road train due to the separate control of individual wheels of the trailer link.

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Кайдалов Р, Омельченко В, Подригало М. **Аналіз існуючих конструкцій автопоїздів з активними причіпними ланками**

Визначена роль автомобільного транспорту з виконання логістичних перевезень та показана їх особливість при здійсненні військовими формуваннями, а саме, більш широкий діапазон змін умов експлуатації. Звернуто увагу на те, що здебільшого для автомобільних перевезень залучаються як одиночні вантажні автомобілі так і автомобільні поїзди. Зазначено переваги використання автопоїздів у порівнянні з одиночними автомобілями при виконанні перевезень. Показано, що у сучасному автомобілебудуванні активно розвивається напрямок, пов'язаний із застосуванням багатовісних великовантажних автопоїздів та зчленованих самохідних платформ. Широке поширення і подальше вдосконалення зазначених транспортних засобів обумовлено великою кількістю об'єктивних чинників.

Встановлено протиріччя між існуючими конструкціями автопоїздів та вимогами щодо ефективності автомобільних перевезень, особливо військових. Вказано на один із напрямків підвищення ефективності автомобільних перевезень за рахунок використання автопоїздів з активними причіпними ланками. Проаналізовано існуючі конструкції автопоїздів з активними причіпними ланками. Визначено особливості конструкції, переваги та недоліки активних ланок автопоїздів різних типів передачі енергії. Виявлено, ефективність різних трансмісій системи приводу активних осей причіпних ланок, а саме: механічних, гідрооб'ємних та електричних для досягнення максимальної прохідності та динамічності у широкому діапазоні умов експлуатації автопоїздів.

Обґрунтовано, що найбільш перспективним є використання електричного (чи електромеханічного) приводу на колеса причіпних ланок автопоїзда, що дозволить спростити конструкцію трансмісії, а в перспективі підвищити прохідність та динамічність автопоїзда за рахунок роздільного керування окремими колесами.

Ключові слова: автопоїзд, активний причіп, трансмісія, причіпна ланка, прохідність.

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