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TITLE:

NEW APPROACHES TO THE BRAKE SYSTEM DESING FOR TRUCK

Topic:

- ● FUTURE AUTOMOTIVE TECHNOLOGY
- ○ INTELLIGENT TRANSPORTATION SYSTEMS
- ○ USER FRIENDLY AUTOMOBILE
- ○ ADVANCED PRODUCTION AND LOGISTICS
- ○ VEHICLES & THE ENVIRONMENT

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Abstract:

At present time the problems of enhancing safety and finding new energy sources are very actual for the world automotive industry. The developments in the field of brake design are dominant from the viewpoint of this aspect.
In the present paper the different layouts for truck brake systems are discussed as well as the solutions directed to enhance the active driving safety.
The brake drives with kinetic boosters were analyzed and also the construction of brake drive with kinetic booster using power take-off from a wheel was proposed as further investigations.
In addition, the original hydraulic anti-lock braking system structure for truck is elaborated and their principal technical data were determined.

Place / Date:

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INTRODUCTION: OBJECT AND RESEARCH TASKS

At present time the problem of enhancing safety is very actual for the world automotive industry. The developments in the field of brake design are dominant from the viewpoint of this aspect.

The main aim of investigation was to elaborate the brake system for truck with the use of solutions directed to enhance the active driving safety. The development of brake system was carried out for a truck with the following technical data (Table 1).

Table 1.

Truck technical data

Gross mass of truck, kg	10100
Gross mass distribution: - on front axle, kg - on rear axle, kg	 3750 6350
Equipped truck mass, kg	5150
Carrying capacity, kg	4800
Tyres dimensions	235/75R17.5
Brakes	Drum-type, pneumatic drive

The pneumatic brake system is widespread in most of modern trucks. Within the bounds of this investigation the problem of transferring the system from pneumatic to hydraulic drive or Brake-by-Wire was examined. It was important to take into consideration the specific of subject (not high carrying capacity) and also the possibility to use modern and perspective mechatronic technologies.

The hydraulic brake system has a number of substantial advantages in comparison with pneumatic one:

1. High response speed
2. Better assembling
3. More efficient distribution of drive forces between front and rear brake gears
4. High efficiency factor (about 0,95)
5. Considerable economic advantage.

During the investigation the well-known and alternative constructions were analyzed (Fig. 1).

The results of preliminary calculation show that:

1. The parallel drive with vacuum booster is not appropriate for use because in this case a vacuum pump has large overall dimensions and high technical requirements.

2. The application of direct action drive with hydraulic booster on the one hand makes it possible to provide a sufficient brake pressure (about 100-150 bar) and on the other hand it is necessary to take power take-off from a steering control pump. This requires additional tests.

3. The installation of Brake-by-wire systems with disk brake gears is not appropriate for use because the patent and literature search did not find out the mechanisms with enough power and effectiveness for truck under consideration.

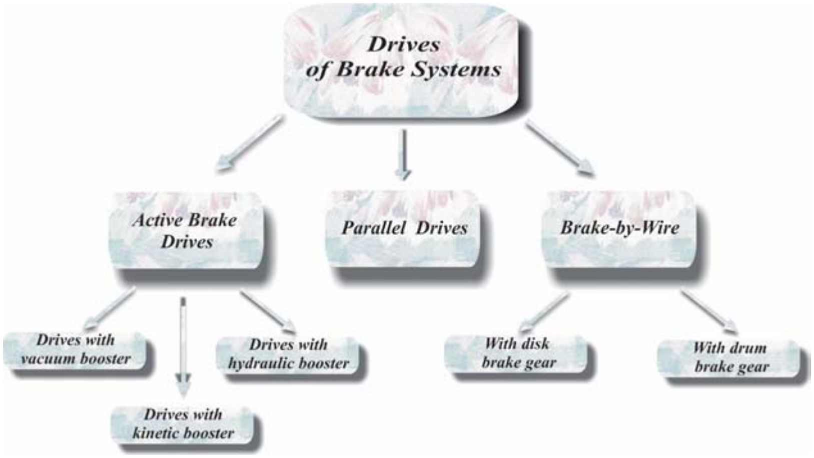

Fig. 1. Drives of brake systems

So, a decision was made to elaborate the design variations of active brake drives, parallel drives with kinetic booster and drum brake gears for automobile to be designed. The main object of this work was the development of various brake systems for the value analysis.

The constructive features for each variations of proposed brake system are being considered.

ACTIVE BRAKE DRIVE

On the basis of constructive analysis the front/rear split of brake system equipped with the anti-lock brake (ABS) system was chosen [1].

Figure 2 shows the layout of a developed brake system equipped with the anti-lock brake system for the automobile to be designed.

The brake system under consideration consists of:

- Hydraulic control unit, located between master and wheels cylinders
- Angular-speed sensors installed at each wheel and the main gear
- Electronic control unit
- Braking torque sensors
- The pressure sensors in master and wheels cylinders
- Suspension sensor

The anti-lock brake system construction is an integrated version and it does not require changes the construction or the layout of main brake system.

The main principle of the calculation is the conformity of brake system with the international normative documents, viz ECE UN 13 Regulation.

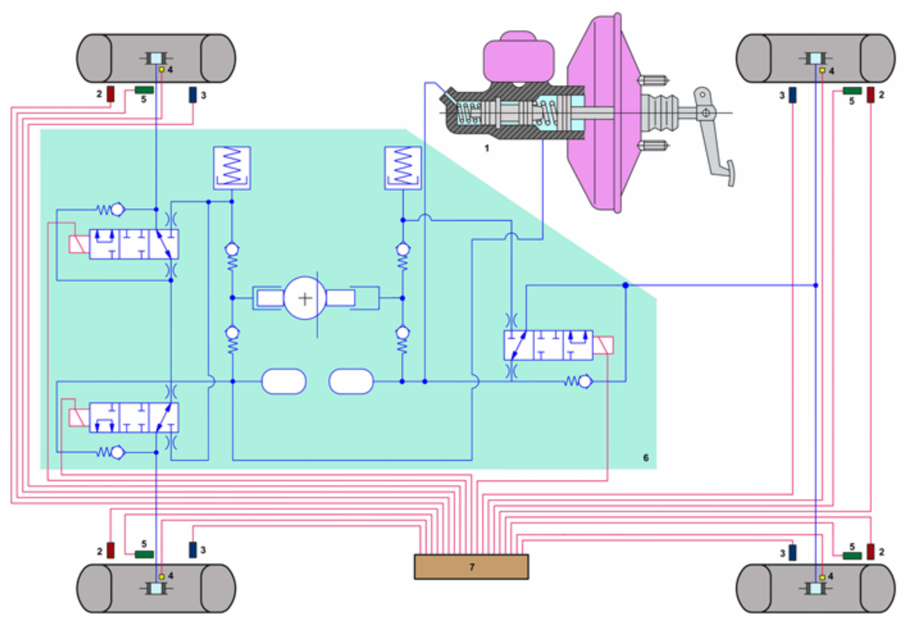

Fig. 2. The Layout of Brake System

To provide the dynamic stability during the brake process it is required that the rear wheels should be not blocked first in the most driving conditions. The rear wheels of trucks are assumed blocked first at critical specific deceleration about 0,3. This critical deceleration changes depending on degree of truck loading because the rear axle load changes within the wide limits. The distribution of brake forces is chosen according to deceleration of equipped truck as the most critical operational situation. The results of computation are shown in Table 2.

Table 2

Characteristic parameters of brake system

Diameter of front wheel brake cylinders, mm	42.27
Diameter of rear wheel brake cylinders, mm	28.57
Diameter of the master brake cylinder, mm	30.00
Transmission ratio of the treadle drive	2
Amplification constant of the booster	3

The obtained design data for braking elements and their arranging analysis allow to make the following conclusions:

1. It is possible to install the small-size wheel brake cylinders to produce this brake pressure level.

2. Analysis of the influence of brake pump on the on-board network is required. At the same time it is appropriate the additional power source installation to provide the energy for pump and elements of anti-lock brake system.

3. Active brake drive provides a high response speed of actuators. It is very important for anti-lock brake system operation.

PARALLEL DRIVE WITH KINETIC BOOSTER

The investigation of brake system variant with parallel action was made as an alternative to traditional brake systems. The principal feature of such brake drive is the power take-off from energy of the moving vehicle for booster operation. In such systems the braking torque creation is carried out with the use of inertial or accelerative forces of vehicle-road interaction [2].

The on-board network, engine, transmission and a single wheel can be used as a transmitting element.

The layouts of power take-off from a single wheel (Fig. 3) and transmission (Fig. 4) were chosen for detailed treatment.

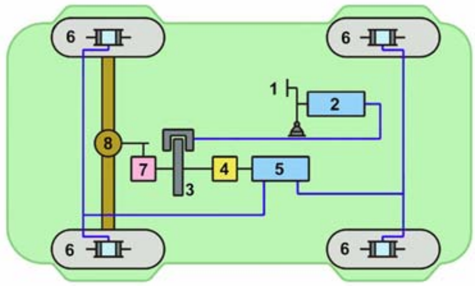

Fig. 3. Kinetic booster with power take-off from a wheel

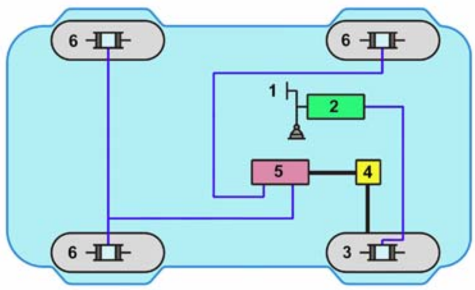

Fig. 4. Kinetic booster with power take-off from the transmission

<u>Kinetic booster with power take-off from a single wheel</u>

In this scheme the pedal cylinder 2 operates a single wheel brake cylinder. Brake gear 3 performs functions of a booster. Brake support is connected with reversing gear 4 of the master brake cylinder 5 putting into operation brake gears of other wheels 6 (Fig. 3).

A brake booster works with stepping on a pedal 1. When moving, the wheel with pressed brake shoes to brake drum turn to an angle determined by the gap in other wheel brake cylinders, necessary fluid flow from the master brake cylinder 5. All the wheels will be slowed using the reversing gear and master brake cylinder. The brake booster will be in state of equilibrium between brake forces in contact wheel/road and force into the reversing gear, depending on pressure in other wheel brake cylinders.

Advantages:

- Simple construction,
- The layout can be used not only a single car but a trailer,
- High operation speed, which is in proportion to initial brake velocity.

Disadvantages: a reversing gear is needed.

Technical data of the kinetic booster with a power take-off from a single wheel:

- Brake torque on each wheel, kNm	15
- Drive pressure, bar	150
- Wheel brake cylinder diameter, mm	52
- Pedal cylinder diameter, mm	13
- Master cylinder diameter, mm	10
- Maximum pedal effort, N	420
- Drive response time (by initial speed of braking 60 kph), ms	0,6

Kinetic booster with power take-off from the transmission

In the given layout the power take-off for booster operation performs from the transmission of a vehicle. The booster 3 through matching unit is connected with the transmission. The brake support with the master brake cylinder is connected through the reverse gear 4.

The brake shoes of auxiliary brake 3 will be pressed to brake drum during the stepping on a pedal 1. The brake drum will begin to rotate because of the connection with a transmission shaft. Support through the reversing gear activates the cylinder 5 which will brake other cylinders 6.

Advantages:

- High speed operation because of simple kinematical connections,
- There are no restrictions to the master brake cylinder parameters.

Disadvantages: a reversing gear is needed.

Technical data of the kinetic booster with a power take-off from an vehicle transmission:

- Brake torque on each wheel, kNm	15
- Drive pressure, bar	150
- Wheel brake cylinder diameter, mm	52
- Pedal cylinder diameter, mm	16
- Master cylinder diameter, mm	31
- Booster brake torque, kN	1
- Brake-booster cylinder, mm	36
- Maximum pedal effort, N	420
- Drive response time (by initial speed of braking 50 kph), ms	23

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The analysis allows to make the following conclusions:

1. Kinetic booster can provide the spreading of hydraulic and electro-hydraulic drives for heavy-duty trucks.

2. This kind of drive does not consume energy from the exterior sources when car moves.

3. Kinetic booster creates the controlled braking torque. It gives the future trends for the kinetic booster integration into Brake-by-Wire systems.

BRAKE-BY-WIRE

As noted above Brake-by-Wire system with drum brake gear was taken as a version for a truck to be considered. The following combinations of brake-by-wire assembling are known:

1. *Hydraulic part* – from the master brake cylinder to hydraulic control unit; from hydraulic control unit to front wheel brake cylinders. *Electric part* – from hydraulic control unit to rear wheel brake cylinders; from brake pedal to hydraulic control unit.

2. Hydraulic part – from the individual hydraulic control units of each wheel to wheel brake cylinders. Electric part –from brake pedal to hydraulic control units.

3. The full electromechanical drive of all brake gears.

The second version using the data of previous analysis was chosen as a basic one. The main feature of the developed system is the double drum brake gear (Fig. 5).

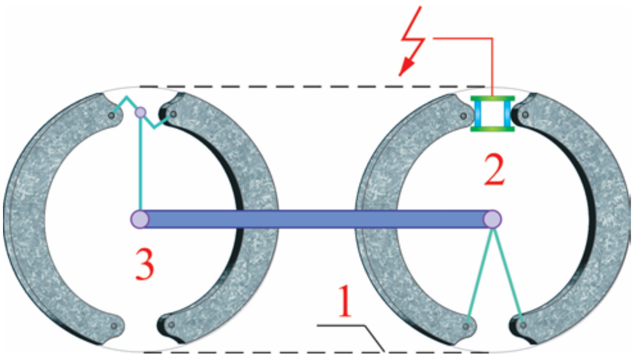

Fig. 5. The construction of the double drum brake gear.

The principle of its operation is similar to kinetic boosters.

The construction of given device is considered. Two brake gears are in the brake drum 1. Brake gear 2 controls brake gear 3 through electrical network. So the brake gear 2 performs functions of kinetic booster. It interacts with the brake drum and creates the active braking torque. Reactive moment controls the brake gear 3 through the releasing device. The braking torques of both brake gears are summed at the brake drum.

In the given layout there is a need of rigid connection between the brake booster support and the releasing device.

The drive works in the following way. The electric releasing device 2 is activated with stepping on a pedal. Its brake shoes are pressed to a brake drum. The brake booster rotates in the same direction as the brake drum. Its support rotates the releasing device of brake gear 3 and activates it. The real braking torque is the sum of two torques, as the brake shoes of the main and auxiliary brake gears are pressed to the drum.

So, active braking torque of the booster creates the additional braking torque using power take-off. Reactive moment is used control the main brake gear.

According to the parameters of the pre-production model the main design parameters of brake gear are:

Width of brake shoes for the main gear, mm	18
Width of brake shoes for the booster, mm	20
Radius of brake drum, mm	180
Diameter of wheel brake cylinder, mm	22,22
Working brake pressure, bar	100
Highest braking torque, kNm	18

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The analysis of the brake system layouts allows to make the following conclusions:

1. The hydraulic brake drives family can be proposed for using of the truck under consideration. The drives differ in working brake pressure, number of actuators and means of consuming the energy.

2. It is possible to install the active hydraulic drive if the on-board network has enough power. Taking into consideration the well-study constructions it is most preferable for lightweight trucks.

3. The drives with kinetic boosters are of great interest. There is no need of the external energy sources for their operation. But it is necessary to perform the additional research work for assembling them with anti-lock brake system.

PROSPECTIVE INVESTIGATIONS: SOME ASPECTS OF HYDRAULIC ANTI-LOCK BRAKE SYSTEMS FOR TRUCKS

As an investigation task the evaluation of ABS parameters for designed truck was made. Taking into consideration the available sensor base the layout of system was offered.

<u>Evaluation of the ABS parameters</u>

The main evaluating parameter of ABS, describing its interaction with brake drive, is the operational frequency. The vehicle behavior in different critical situations conditions is taken as a basis. In current work the method of evaluation of ABS reaction on discontinuous fall of the road surface friction coefficient is used [1]. The calculated time of bloking wheel was 0.18 c. It corresponds to 5,5 Hz. The hydraulic brake systems can provide frequency about 12…20 Hz. The conclusion was made, that hydraulic drive matches anti-lock brake system

<u>Distinctive features of anti-lock brake system structure</u>

The suggested control principle of anti-lock brake system is based on the fact that, mu-slip diagram has almost a linear character in pre-extremal period of movement. So, for the algorithm of anti-lock brake system **dμ/ds** sign derivative changing can be used.

The ABS tests show that the derivative **dFμ/dF$_c$** also has the similar character [3]. So, this characteristic was taken as a controlling one for anti-lock brake system. Fig. 6 displays the algorithm layout of system operation.

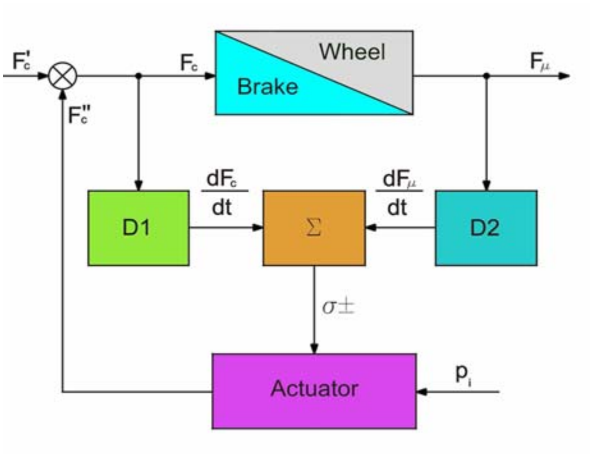

Fig. 6. The layout of gradient pre-extremal system

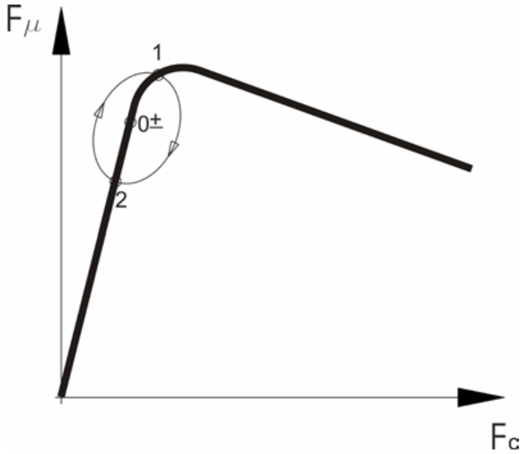

Fig. 7. Layout of system action

One of the main features of this algorithm is the use of gradient search method. The farther the current system position from extreme point is assumed, the stronger the tilting of **Fμ(F$_c$)** characteristics. This is determined by the use of the gradient module.

$$grad[F\mu(F_c)] = \frac{dF\mu}{dF_c}$$

The control action for this system is formed with the help of **(dFμ/dt)/(dF$_c$/dt)** correlation. The logic element Σ analyses this correlation and processes the time derivatives of quality index and control action. These time derivatives are produced by the differentiating devices D1 and D2. The signal of direction of the actuator is formed at the output. It is formed according to the following law:

$$\begin{cases} \sigma = sign\left(\frac{d}{dF_c}\left(\frac{dF\mu}{dF_c}\right)\right) + \chi_1 \quad at \quad \frac{d}{dF_c}\left(\frac{d}{dF_c}\left(\frac{dF\mu}{dF_c}\right)\right) > 0 \\ \sigma = sign\left(\frac{d}{dF_c}\left(\frac{dF\mu}{dF_c}\right)\right) - \chi_2 \quad at \quad \frac{d}{dF_c}\left(\frac{d}{dF_c}\left(\frac{dF\mu}{dF_c}\right)\right) < 0 \end{cases}$$

Figure 7 shows the layout of system action

The value of first derivative **dFμ/dF$_c$** in the point 0 (curvature changing) changes sign. The system is inert, so the pressure exhaust will start from point 1 rather than point 0. In the point 2 the next actuator will start to increase pressure. So, it will be the oscillation near the area of point 0.

CONCLUSION

1. Different layouts for truck brake systems were discussed as well as the solutions directed to enhance the active driving safety.

2. The brake drives with kinetic boosters were analyzed and also the construction of brake drive with kinetic booster using power take-off from a wheel was proposed as further investigations.

3. The original hydraulic anti-lock braking system structure for truck is elaborated and their principal technical data were determined.

NOMENCLATURE

$\mathbf{F_c}$ - Control effort on a brake gear
$\mathbf{F\mu}$ - Force within a wheel-road-contact
s - Wheel slip (sliding)
μ - Specific force within a wheel-road contact, coefficient of the wheel's cohesion

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