The motor brake of a compressor type

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Abstract. The accident rate in road transport remains very high and it is necessary to consider all the factors that affect this process to reduce it. In this regard, special attention should be paid to the process of long-term braking, the negative manifestations of which require the development of additional braking systems (retarding retarders) for vehicles operating in mountainous areas, primarily in the sphere of passenger transport. Transmission retarder brakes, which provide sufficient braking performance, have a number of disadvantages that hinder their use. The existing motor brakes-retarders show insufficient retardation and Kuban State Agrarian University conducted researches to improve their effectiveness. The compressor brake mode was experimentally studied after the theoretical analysis, in which an increased pressure was created in the inlet collector, and at the end of the compression stroke, the air from the cylinder was released through a special valve back into the system, which created the braking effect. The experiments have confirmed the possibility of a significant increase in the braking torque of the engine in the compressor brake mode, when both flaps are closed - the exhaust flap after the exhaust collector and the inlet collector before the carburetor, and compressed air is supplied to the inlet collector at different pressures. Then the braking torque increases in comparison with the engine braking more than 3 times.

1. Introduction
When driving a car on a lengthy descent or with repeated frequent braking, the brakes overheat in the friction zone, where various researchers record temperatures up to 300-370°C, and sometimes higher. In these conditions the overheating of brake pads, their charring, pitting and warping of the brake drum or brake disk occur [1].

When the brake pads are heated, released substances act as a lubricant and reduce the coefficient of friction by half or more. A decrease in deceleration during braking on a long descent with a slope of 3-4° and a length of 19 km was recorded from 5.6 m/s² to 2.6 m/s² in tests conducted by Russian Automobile and Automotive Research Institute.

At a high temperature of brake pads during operation, their wear increases dramatically – they have to be changed not after 70-90 thousand kilometers, but after 8-10 thousand kilometers. At the same time, the pad friction coefficient decreases and the braking distance of a car increases. Reducing the level of traffic safety decreases the labor productivity of a driver, as the average speed decreases [2].

Attempts to use the engine braking mode on a lengthy descent lead to an increase in the vacuum in the inlet collector and, as a result, to the suction of oil into the combustion chamber. In addition, the carbon monoxide content in the exhaust gases increases almost in 6 times in the forced idle mode of the engine when braking [3].
The exhaust brake is simple and cheap, since, in essence, it simply includes a flap after the exhaust collector. When braking, the ignition is switched off and the braking effect is created by the back pressure from the exhaust collector on the upward stroke of the piston. However, the braking efficiency of the exhaust brake is insufficient.

It is reasonable to install the effective retarding brakes, first of all, for passenger cars operating in mountainous conditions. It will allow us to slow down the car when there is no need for emergency braking. In addition, there is a backup brake system, which increases traffic safety.

Retarding brakes can be transmission and motor type. Transmission retarding brakes can be hydrodynamic and electrodynamic, the exhaust brake patented in the early twentieth century, mainly, is known as a motor brake [4].

The retarding brakes with radial blades of the Thompson Company are most often used as hydrodynamic retarding brakes. The brake is attached either to the frame or to the crankcase of the rear axle. The weight is 80-96 kg. The working fluid is a mineral oil that can be displaced by compressed air from the compensation cylinder into the brake housing. The absorbed power is controlled by the compressed air pressure, as it determines the fluid level in the brake housing.

There are other designs of hydrodynamic brakes. In this capacity, a torque converter can be used, in which the level of braking is regulated by the amount of oil in the housing. There was also developed the brake in which a gear mounted on the driveshaft was permanently engaged with two other gears, forming two oil pumps. When braking, the pressure valves of the pumps were locked, but this caused a strong increase in the oil temperature.

The most famous electrodynamic brake was developed by the French Company Telma. It consists of a stator mounted on a frame with induction coils that are powered by a battery and create a magnetic field. The brake rotor is connected to the driveshaft. The braking moment occurs as a result of the interaction of the magnetic fields of the stator and the eddy current fields of the rotor. The rotor has blades for cooling, since its disks can heat up to a cherry-red color during operation. The Telma brake weighs 100kg for a car weighing 6 tons.

Transmission retarding brakes provide deceleration up to 1.5 m/s², but have a number of disadvantages. The hydrodynamic brake is characterized by high cost, bulkiness and the need for additional maintenance. The electrodynamic brake, in addition to its high cost, bulkiness, and heavy weight, usually requires an additional battery pack. All these disadvantages prevent the widespread use of transmission retarding brakes.

2. Materials and methods

70 h/p carburetor engine at a nominal speed of 2800 rp/m and a maximum torque of 20 kg/m, it was installed on an electric brake stand, which during tests worked in the mode of an electric motor. To increase the number of revolutions of the crankshaft, the torque was transmitted through one of the lower stages of the gearbox. The clutch driven plate was removed and replaced with a strain gauge link.

Since the slip current collector operates reliably at a speed of no more than 2000 rpm, an end collector was used to transmit the pulse from the strain member at higher revolutions. The conductive line passed through the crankshaft, in which special channels were made by electric spark treatment and after the line was laid, special channels were filled with epoxy resin. The electrical impulse from the strain-link was removed by an end collector from the toe of the crankshaft and recorded on an oscillogram, where the rotation frequency was simultaneously recorded.

Braking performance tests were conducted with engine braking, exhaust brake, high efficiency exhaust brake, and compressor mode. In the exhaust brake mode, a damper was installed after the exhaust manifold and the braking torque was determined at different speeds of rotation of the crankshaft. In the high efficiency exhaust brake mode, two flaps were closed, one after the exhaust manifold and one in front of the carburetor.

Compressed air was supplied from a stationary compressor to the engine cylinders at different pressures, after which the braking efficiency was determined.
3. Discussions and results
The braking characteristics of the engine in the mode of the exhaust brake and the exhaust brake with increased efficiency at different speed modes are presented in Table 1.

Table 1. Braking characteristic of the engine in the mode of the exhaust brake with increased efficiency.

| Mode                                      | The number of engine revolutions per minute |
|-------------------------------------------|--------------------------------------------|
| Braking mode                              | 800 1200 1600 2000 2400                    |
| Engine braking                            |                                            |
| - braking torque, Nm                      | 40 48 54 60 72                             |
| Exhaust brake                             |                                            |
| - braking torque, Nm                      | 90 102 116 130 156                         |
| Exhaust brake with increased efficiency at p = 3 kg/cm² - braking torque, Nm | 104 116 128 132 162 |
| Exhaust brake with increased efficiency at p = 4 kg/cm² - braking torque, Nm | 116 128 140 152 172 |
| Exhaust brake with increased efficiency at p = 5 kg/cm² - braking torque, Nm | 128 138 152 168 178 |

Thus, the braking torque increases 2.5 - 3.2 times compared to engine braking in the mode of the exhaust brake with increased efficiency at a pressure of the supplied compressed air of 5 kg/cm². The strength conditions of the engine parts are met in this case.

In order to improve the operating conditions of the engine and increase the braking efficiency, the compressor brake mode was tested, in which air was discharged from the cylinder at the end of the compression stroke through a special valve installed in the block head. The braking characteristic of the engine in the compressor mode was determined at a pressure of the supplied compressed air from 1 to 4 kg/cm².

The results of the compressor mode tests at different compressed air pressures are shown in Table 2.

Table 2. Braking characteristic of the engine in compressor mode at different pressures of the supplied compressed air.

| Mode                                      | The number of engine revolutions per minute |
|-------------------------------------------|--------------------------------------------|
| Braking mode                              | 800 1200 1600 2000                         |
| Compressor brake at p=1 kg/cm²            |                                            |
- braking torque, Nm

Compressor brake at $p=2 \text{ kg/cm}^2$
- braking torque, Nm

Compressor brake at $p=3 \text{ kg/cm}^2$
- braking torque, Nm

Compressor brake at $p=4 \text{ kg/cm}^2$
- braking torque, Nm

The condition of the strengthening of all engine parts during the transition to the compressor mode is met, since the operating pressure of the exhaust valve is significantly lower than the pressure of the end of combustion. The braking torque of the engine in this mode, when compressed air is supplied at a pressure of 196 kN/m$^2$, exceeds the braking torque in the normal braking mode of the engine by more than 3 times.

4. Conclusion
Transmission retarding brakes are not widely used in cars due to their high cost, significant weight and the need for additional maintenance.

Prolonged braking by the engine on lengthy descents leads to the flow of oil into the combustion chamber and additional carbon monoxide emissions into atmosphere, and in this case, the deceleration happened is small.

The compressor brake mode, which is characterized by its simple design and low cost, creating a high braking torque, can be recommended for vehicles operating in mountainous conditions.

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