INVESTIGATION OF THE PULSATING BRAKING

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Introduction

Studies of road accidents show that the loss of the control and stability of vehicles during braking is a common feature of motor vehicles. Efforts have been constantly made to achieve the shortest possibles topping distance without affecting the stability or controllability of a vehicle, in order to control the braking torque at each wheal so as to produce the greatest possible contribution of that wheel to the total retarding force applied to the vehicle. This principle has been recognized as early as in 1907 (1). Two main approaches have been employed. The first one utilizes the open loop control of the braking torque reacting to one or more measured variables. Such a controller is the so-called "sensing proportioning valve". The principle of the open loop scheme involves a number of errors always resulting in the loss of the vehicle's stability under different conditions (2). Moreover, the vehicles provided with open loop controllers always loose the controllability during powerful braking. The second is a closed loop controller sensing the wheel's rotation and modulating the braking to avoid the lock of the wheel; this kind of controllers are named "antilock devices". The antilock device could respond to the problem of making the braking proportional. But the current antilock systems are relatively complex and very expensive compared to the price of a vehicle. Moreover, the antilock system's reliability in a passenger car is yet unproven; its benefits in providing better stability and controllability in case of panic-stop-situations are unquestionable (1).

As shown above, the vehicle stability and controllability problems cannot be solved by using the open-loop controller. And in view of the antilock scheme costs and maintenance requirements it is impossible to provide all vehicles with an antilock device.

As a conclusion, a new concept is needed for improving the current brake systems, to avoid the loss of vehicle stability and controllability, resulting always in dramatic situations. This concept depends on the pulsation, of the brake-oil supply to the front and rear wheels of the vehicle. In the new system the brake-servo is the pulsator operating according to a three-way solenoid valve applied to regulate the direction of the servo vacuum. The system's characteristics and mode of operation will be described later.

Road tests were performed using the conventional and the pulsating brake systems. The obtained results indicate a possibility to avoid wheel-lock and to improve the vehicle stability and controllability by using the pulsating brake system.

Description of the pulsating brake system

The operational concept of the system depends on the brake-servo-vacuum pulsation. This process will change the servo output in to a pulsating form. Level and amplitude of the pulses mainly depend on the brake-pedal force. The pulse frequency is controlled by regulating the servo vacuum by a three-way solenoid valve controlled by an electronic pulsator. The three-way valve has the following functions:

1) opening the engine's vacuum line to the servo;
2) opening the servo vacuum line to the atmosphere and at the same time closing the engine's vacuum line;

Fig. 1 shows the pulsating brake-system containing the following components:

a) brake-master (1)
b) brake-servo (2)
c) three-way solenoid air valve (3)
d) 5 DC—V power supply (4)
e) electronic pulsator (5)
f) 5 DC—V power supply switch integrated with the stop-light-switch (6).

Fig. 2 shows the electronic circuit of the designed electronic pulsator. The system is clearly simple and unexpensive compared to other controller schemes.

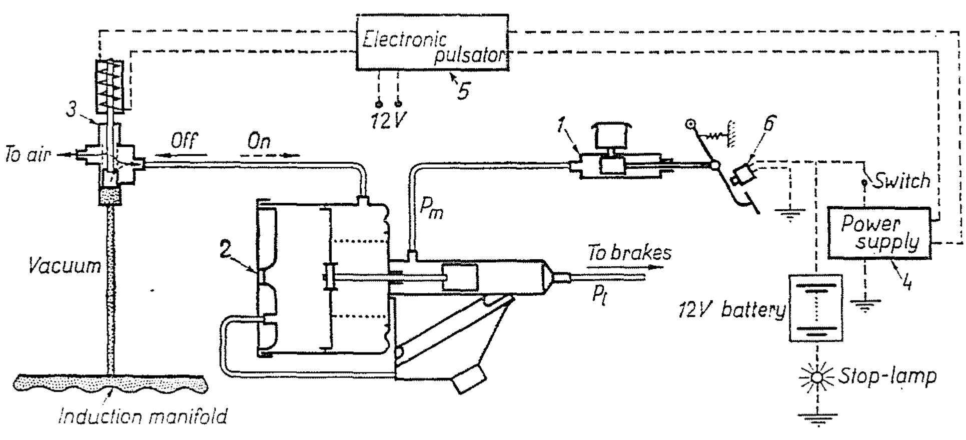

Fig. 1. The pulsating brake system

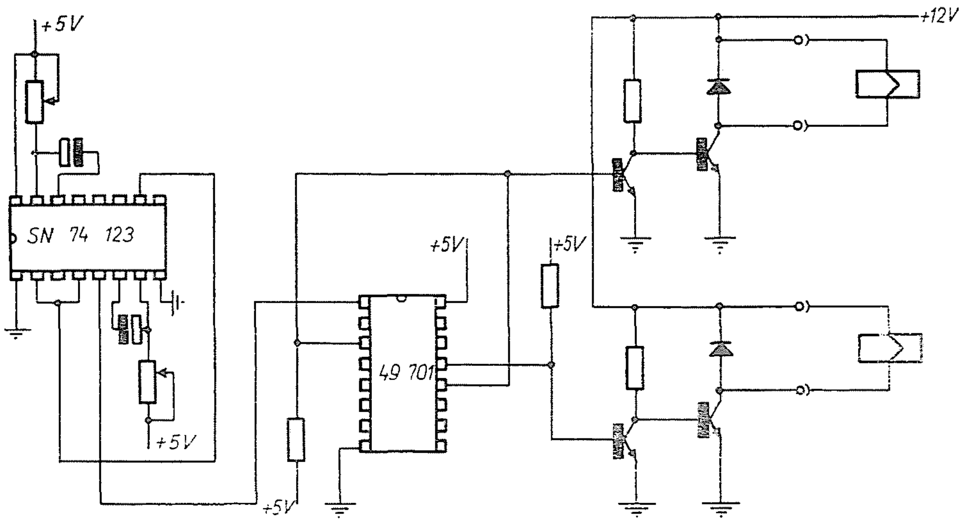

Fig. 2. The designed electronic pulsator circuit

The pulsating system used in the test car operates automatically when the driver applies the brake. The system operates as follows: When the driver is braking, the stop-light-switch (6) opens the power supply (4) and in this moment the electronic pulsator activates the three-way valve (3) according to the required frequency controlled by adjusting a rotate potenciometer.

The characteristics of the system

In this system the brake servo characteristics are decisive for the whole system's characteristics. The servo in this system has a new plus-function since it works as a pulsator and partially controls the amplitude of the pulses. Therefore, the choice of the suitable servo mainly depends on its reaction and capacity when it opens or closes the vacuum. Fig. 3 shows a wide spectrum of servo characteristics with different capacities. The used servo characteristic is given in Fig. 4. Naturally, the used servo is relatively small compared to types shown in Fig. 3. The drawbacks of such a small capacity servo will be discussed later.

The form of the required pulses is seen in Fig. 5. It is evident that the oil pressure fluctuates between two fixed limits: the first is the brake master line output pressure p_m and the second is the servo output pressure line p_0. It is also evident that the rate of the increase of the amplitude is increasing with the pedal force and the pulse amplitude itself mainly depends on the used servo characteristics and capacity (gain).

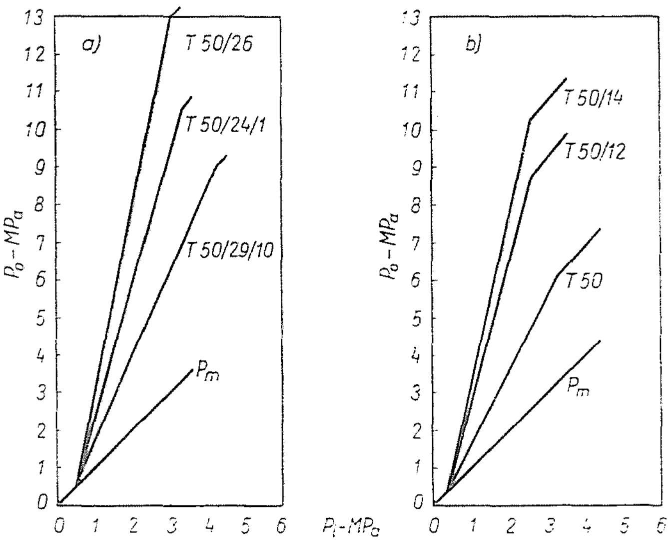

Fig. 3. GMBH-servo-type characteristics

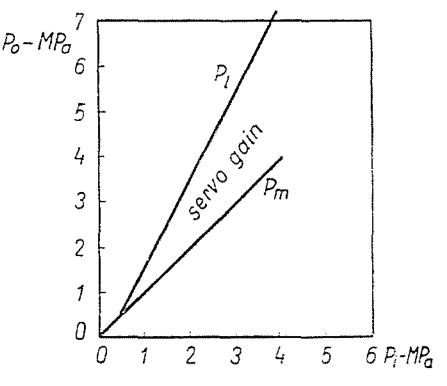

Fig. 4. The used servo characteristic

The servo response to the opening or closing of the vacuum was found to be very important at frequencies higher than 2 Hz. Fig. 6 shows the resultant pulses at frequencies f_p higher than 2 Hz to much deviate from the expected form. This means that, at frequencies higher than 2 Hz, the used servo must be more sensitive and have a greater capacity in order to produce pulses with suitable amplitude.

Therefore it is expected that the pulsating system will not be effective at frequencies higher than 2 Hz when a servo of improper size is applied.

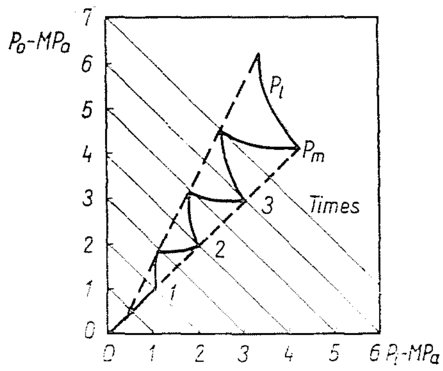

Fig. 5. The expected pulsating pressure form

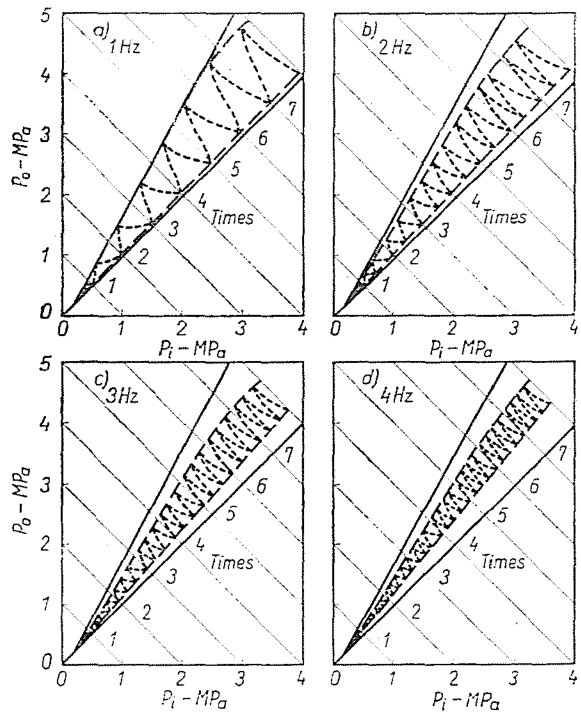

Fig. 6. Effect of the pulsating vacuum frequencies on the pulsating oil pressure amplitude

Test procedure and measurements

Road tests were performed with a passenger car type Lada 1200. The test car was subjected to braking tests performed at straightforward running. These tests were made using either the conventional or the newly designed pulsating brake systems.

The experimental work consisted of two parts:
1. braking with the front wheels alone;
2. braking with all wheels.
During the tests the following parameters have been measured:
1. time;
2. longitudinal deceleration (A_x);
3. front and rear brake-oil pressure (p_{Lf} and p_{Lr}, respectively);
4. the time needed to lock the front and rear wheels.

The sequence of the measurements and the method itself have been described in a previous work (2).

Braking with the front wheels alone

In all vehicles supplied with sensing proportioning valve, the front wheels cannot be controlled at all. Therefore, loss of controllability is a common feature of these vehicles.

Accordingly, it was interesting to study the required pulsating oil pressure in order to avoid locking of the front wheels.

Fig. 7 shows a typical record of the test results. Fig. 7a shows the brake-oil pressure level producing locking of the front wheels. When the level of pressure is reduced to about 80% of the pressure level producing wheel lock, the wheels will not lock, as seen in Fig. 7c. When the vehicle is braked by means of the pulsating system, it is found that, although the pressure is near the lock level, the wheels do not lock (see Fig. 7b). In these tests the pulse frequency was 1 Hz with 2 MPa amplitude.

Table 1 shows the results obtained at frequencies over 1 Hz. that the wheels are seen to be locked farther for higher pulse frequencies. This phenomenon was attributed mainly to the small capacity and non-sensitivity of the servo used for higher frequencies.

Table 1 (40 km/h)

Surface	fp (Hz)	Amp (MPa)	p_{max} (MPa)	p_{min} (MPa)	Wheels locked?		Stopping time (s)	Locking time (s)
					yes	no		
Dry Asphalt	1	2	10	8		x	2.57	2.5
	2.	1.5	10	8.5	x		3	1.5
	2.8	0.8	10	9.2	x		3.3	0.5

Similar tests were performed on wet asphalt. Fig. 8. shows a typical record of the test results. Figs 8a and 8c show the pressure levels where the

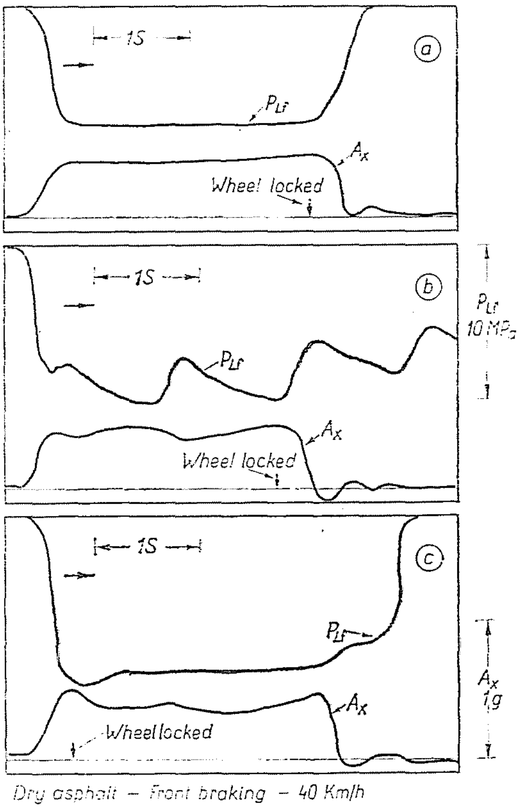

Fig. 7. Braking test results on dry asphalt with and without the pulsating system

wheels were locked or not, respectively. Fig. 8b shows that braking by means of the pulsating system did not result in the locking of the wheels.

The results at different pulse frequencies are given in Table 2.

Table 2 (40 km/h)

Surface	fp (Hz)	Amp (MPa)	p_{max} (MPa)	p_{min} (MPa)	Wheel locked?		Stopping (s)	Locking (s)
					yes	no		
Wet Asphalt	1	1.8	6.5	4.7		x	3.3	3.2
	2	1.6	6.5	4.9		x	3.2	3
	2.8	1.3	6.5	5.2	x		3.9	0.4

The obtained results showed that by means of the pulsating system the wheel lock can be avoided, even when the pressure level was of its maximum value where the wheels absolutely lock if the conventional brake system is used. This result itself is very significant and points to the possibility of using such a system (of course only after more extensive research work aiming at improving the system) in current vehicles.

However, the following questions emerge:

1) What is the advantage of the pulsating system if it operates at a pressure level lower than where the wheels never lock?
2) What is the advantage of the pulsating system if it operates above a pressure level where the wheels always lock?

The answer to the first question is given in Fig. 9. Clearly, the pulsating braking produced a longer stopping distance at the same uncomfort for the passenger. Therefore, pulsating braking is undesirable at a low level of pressure and, it must not be allowed to operate there.

The answer to the second question is given in Fig. 10. The pulses are seen to have no advantage at such high pressure levels. Therefore, the pressure must be regulated not to reach such high levels. Moreover, in such case the pulse amplitude must be greater than usual and so one must have a suitable servo capacity.

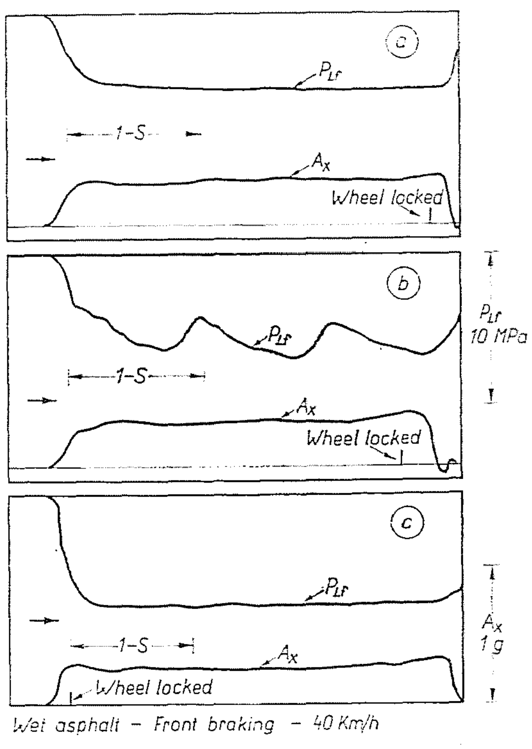

Fig. 8. Braking test results on wet asphalt with and without the pulsating system

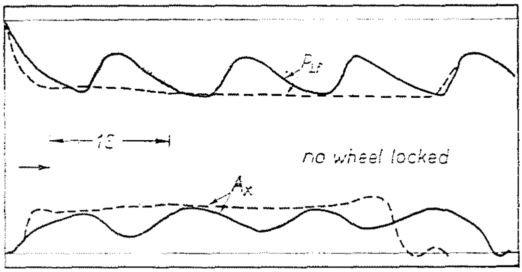

Fig. 9. Braking with low pressure level

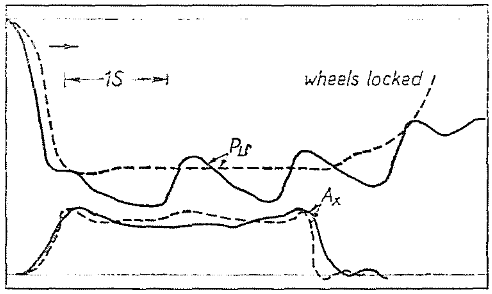

Fig. 10. Braking with high pressure level

Braking with all of the wheels

In this part of the investigations tests were performed by applying pulsating pressure to both front and rear wheels. In these tests the brake sensing valve was not removed. The main purpose of these tests was to study the possibility of improving the vehicle controllability and stability. And, as it the open-loop cut-off controller pressure, is known to produce rear wheel-lock under several different conditions, therefore, application of the pulsating pressure to the rear wheels, within a certain range may cause the controller output to take a pulse form avoiding wheel-lock.

Fig. 11 shows a typical record of the test results and, comparison of 11a and 11b, it can be concluded that the pulsating system may improve both the controllability and the stability, especially in the present case, where the controller cut-off pressure produced rear wheel lock. According to Fig. 11 excellent results have been obtained. But if the oil pressure level is high enough and does not produce locking of the front wheels, the rear wheels will be locked. In this case the application of the pulsating pressure will result in a longer stopping distance but the locking of the rear wheels could be avoided, as shown in Fig. 12. In this case, the pulsating pressure must not be applied to the front wheels put to the rear wheels alone. In other words, the pulsating

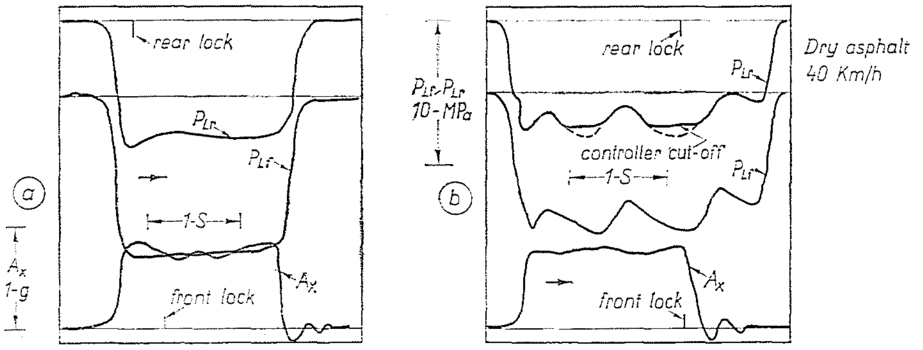

Fig. 11. All-wheels braking test results *a)* with pulses *b)* without pulses

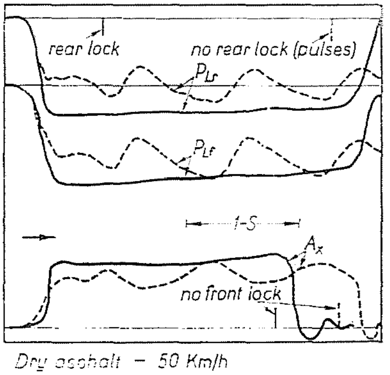

Fig. 12. All-wheels braking test results at low oil pressure on front wheels

pressure can only be applied to the front wheels at a satisfactorily high level of the line pressure.

The obtained results show be benefits of using such a pulsating system in passenger cars. The present concept is likely to contribute to the efforts made to solve the problem of the loss of vehicle controllability and stability in braking.

Summary

Loss of vehicle controllability and stability in braking is an inherent problem in current vehicles. In the present work a new concept to design a pulsating brake-system is described.

Results obtained in road tests showed the possibility of improving vehicle controllability and stability at a relatively high level of oil pressure by using the newly designed pulsating system.

References

1. Bidwell, J. B.: SAE Trans., 1970. paper 700366, pp. 1128—1140.
2. El-Gindy, M. and Ilosvai, L.: Periodica Polytechnica Transp. Eng. Vol. 8 (1980) No. 1

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