CONTRIBUTIONS TO DEVELOPMENT AND TESTING OF CENTRALIZED CONTROL SYSTEM OF INFLATION PRESSURE IN AGRICULTURAL TRACTOR TYRES ACCORDING TO SOIL AND WORKING CONDITIONS

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Abstract. The first part of the paper presents the construction of the centralized control system of tyre inflation pressure for a wheel agricultural tractor, using components from a centralized installation of tyre inflation pressure of an all-road military wheel vehicle. From the air reservoirs of the tractor the compressed air is directed to the central inflation of the pressure control system, where from, by means of the rotating air valves mounted in the axes of the axles, the compressed air reaches the tractor tyres. The last section of the paper presents the results of the experimental research conducted on the influence of the air volume in the reservoir on the response rate of the real-time control system of tyre inflation pressure. The developed and experimentally tested constructive solution can be applied to tractors already in use with minimal adaptations, depending on the concrete construction of the wheel agricultural tractor, or can be included as an option in axle manufacturing.

Keywords: agricultural tractor, tire inflation pressure, central tire inflation system, experimental testing.

Introduction

The shape and size of the contact surface between the wheels of tractors and self-propelled machines and road (soil) and, implicitly, the value of average pressure of tyres on soil, depend on the constructive and exploiting factors of wheel tyres [1; 2]. Among the constructive factors, the tyre carcass (radial or crossing), the shape of tyre contours (toroidal or eliptical) and the tyre dimensions (diameter, width) have the greatest influence. The most important exploiting factor of tyres is the inflation pressure, as the low pressure tyres present a diminished risk of soil compaction in comparison with high pressure tyres. Therefore, a viable solution would be the control system of inflation pressure of the tyres during the movement (travelling), by equipping of tractors and machines with a central system of the tyres inflation pressure, similar to those used for special land vehicles (for example, military wheel vehicles).

The central pressure control system for agricultural tractor tyres during the travelling, usually comprise the following distinct equipments: equipment for preparing the compressed air, equipment for distributing the compressed air and equipment for measuring and control of inflation pressures. At a world level, there are a series of solutions and constructive systems of centralized inflation pressure control systems in tractor tyres during the vehicle travelling [3-5].

The centralized inflation pressure control system in agricultural machine tyres can be applied both to tractors and its coupled machines. Figure 1 shows the scheme of a centralized regulated system of both tractor tyres and trailer tyres inflation pressure, using two reservoirs of compressed air: one for the tractor 2 and the other 3 for the trailer [4].

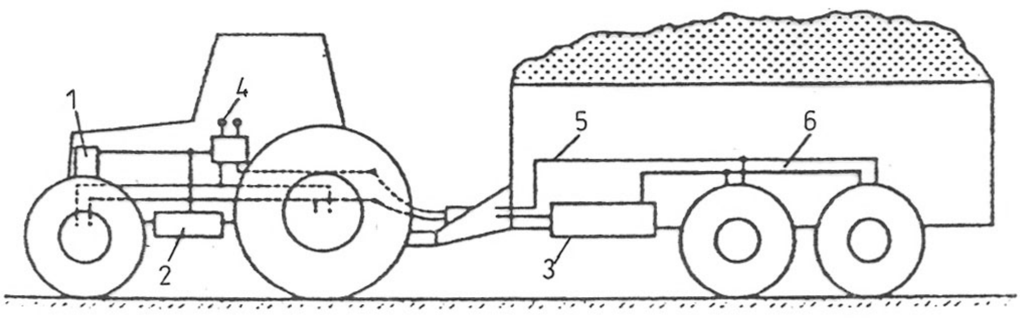

Fig.1. **Scheme of central installation of inflation pressure in tractor-trailer tyres [4]:**
1 – air compressor; 2, 3 – reservoirs of compressed air; 4 – control unit; 5 – control and regulating pipe; 6 – pipe for filling (inflating) tyres

In view of increasing the efficiency of the inflation pressure control system in tractor wheel tyres during the travelling there are concerns (researches) focused on designing an automatical control system, equipped with suitable sensors which concomitantly measure the following parameters: wheels sinking depth into the soil, loads on wheel axles (of front and, respectively, rear axle), tractor travelling speed and wheel slip. The values of pressure within the system (reaction value) are delivered as electrical signals and compared with the reference values (input value), resulting in a deviation signal. By means of a switch, the deviation signal automatically controls the pneumatic circuit for one of two respective states: pressure raising or pressure diminishing in tyres [4; 5].

The advanced systems of controlling the tyre pressure can be also equipped with electrical sensors for measuring the parameters characterizing the concrete state of soil, for instance the degree of soil loosening and soil humidity [4]. Therefore, we can pass to necessary corrections for regulating the tyre inflation pressure on basis of a pre-established strategy created by the operator (driver), as he can better focus on monitoring the working process or the tractor-machine system.

Materials and methods

Conceiving, designing and constructively-functionally achieving a central inflation pressure control system in tractor wheel tyres during the travelling was applied to for a four-wheel drive agricultural tractor U1010 DT (made in Romania), using components from an all-road military wheel vehicle. The used tractor has an engine with a nominal power of 100 HP, and rear wheels are equipped with 16.9-38 tyres type [6]. The total tractor mass was of 4200 kg, out of which 2600 kg on its rear axle and1600 kg on its front axle.

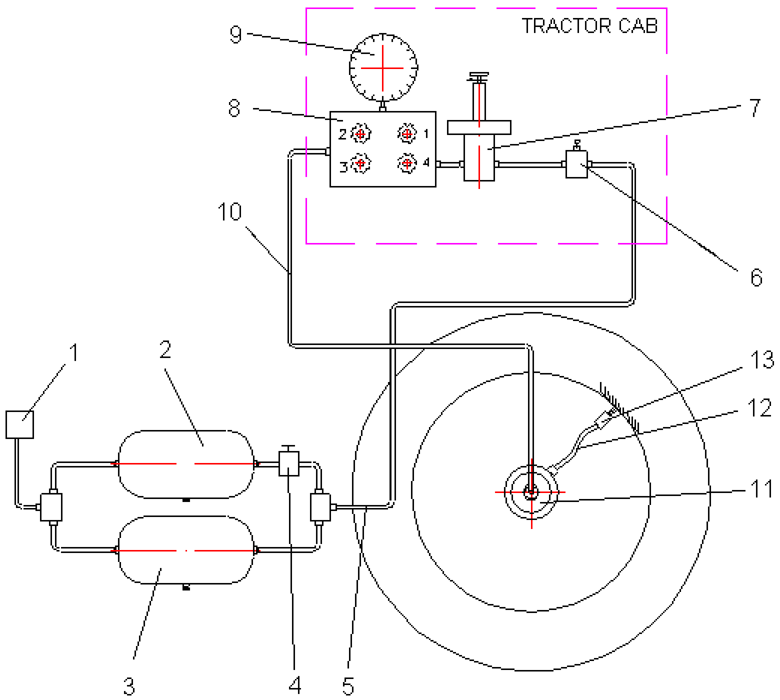

Fig. 2. **Scheme of installation of central inflation pressure control system in tyres of agricultural tractor U 1010 DT:** 1 – tractor air compressor; 2 – tractor air reservoir; 3 – additional air reservoir; 4 – stop valve; 5 – supplying pipe; 6 – direction valve; 7 – pressure regulator; 8 – group of control valves; 9 – air pressure gauge (manometer); 10 – connecting pipes with wheel rotating air distributor; 11 – rotating air distributor; 12 – connecting pipes with wheel shutter; 13 – wheel shutter

For manufacturing this installation of central inflation pressure there have the components of centralized installation belonging to an all-road military wheel vehicle been used. An additional compressed air reservoir, connected in parallel to the normally tractor tank was mounted on the tractor. The scheme of the installation is shown in Figure 2.The compressed air generated by the compressor 1 of the tractor feeds the tractor air reservoir 2 as well as the additional reservoir 3, the two reservoirs being able to act separately or to be connected in parallel through the intermediate of the tap 4. The air leaves the reservoirs through the feeding pipe 5 and passes into the group of control, regulating and measuring the pressure (mounted in tractor cab) and, from here, through the rotative distributors 11 and pipe 12, it reaches the shutters 13 of the tractor wheel tyres.

The equipment of control, regulating and measuring the system pressure comprises a direction valve 6, the air pressure regulator 7, endowed with an adjusting knob and an indicating scale and, a group of control valves 8. The system pressure is measured by the gauge (manometer) 9. In order to increase the tyre pressure (tyres inflation) the knob of the pressure regulator 7 is actuated so that the needle indicates the aimed pressure. The air from the tractor reservoir inflates the tyres according to the required pressure, shown by the pressure gauge 9, after what the pressure remains steady due to the regulating valve. For reducing the tyre pressure (tyre deflating) the needle of the regulating valve is placed at the required pressure, so that the tyre air is released into atmosphere till the moment when the pressure reaches the established value, also indicated on the pressure gauge 9 dial. If the installation circuit remains permanently open, then the pressure in tyres will be kept at the value established by the regulating valve (indicated by the pressure gauge 9).

For the experimental research in the behaviour of the central inflation pressure control system in the wheel tractor tyres, a programme of tests has been elaborated, according to which the period of time necessary for inflating the tyres was measured, framing within two given values, for the following 10 ranges of pressure variation: 0.8...1.0 bar; 1.0...1.2 bar; 1.2...1.4 bar; 1.4...1.6 bar; 0.8...1.2 bar; 0.8...1.4 bar; 0.8...1.6 bar; 1.0...1.4 bar; 1.0...1.6 bar; 1.2...1.6 bar. The installation was alternatively fed from a single reservoir only ($V_1 = 40$ dm^3 volume) and, respectively, from both reservoirs coupled in parallel ($V_2 = 80$ dm^3 volume), thus achieving 20 testing variants.

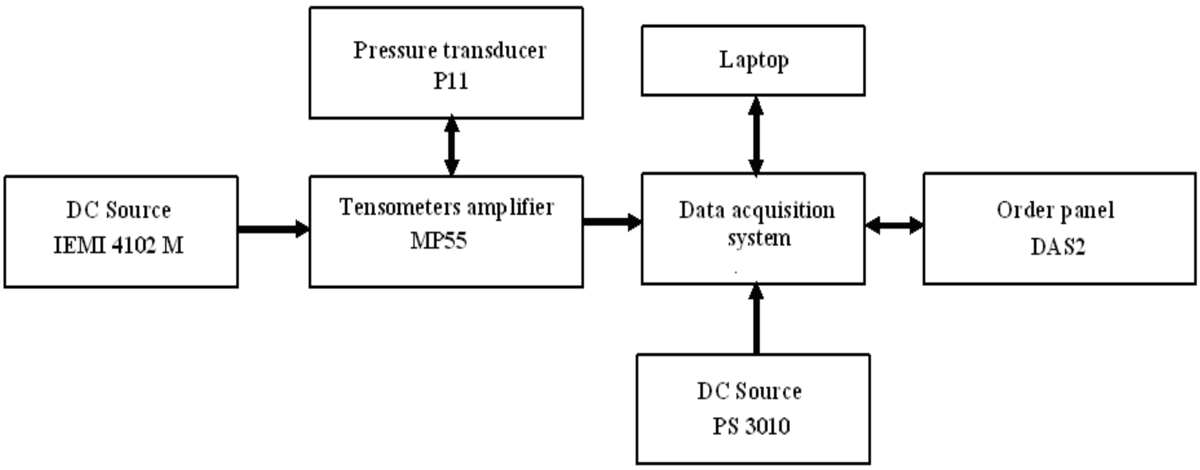

Fig. 3. **Block scheme of installation of measuring inflation pressure of tractor tyres**

In order to reach the experimental research an installation of measuring, acquiring and processing the data has been designed and manufactured (Fig. 3) [6], comprising the following parts: power source of direct current PS 3010, power source of direct current type IEMI 4102 M, inductive pressure transducers type HOTTINGER TIP P1, tensiometer amplifier type MP55, Laptop DELL type, data acquisition system type DAS 3 with switch panel type DAS 2.

Results and discussion

After processing the obtained experimental data the diagrams of variation in time of inflation pressure in the system for the 20 variants of testing have been drawn up. As an example, Figure 4 shows the graphic of time variation of inflation tyres pressure when it is modified from its initial value 1.0 bar to 1.2 bar, with both compressed air reservoirs coupled. In that case the period of time in which the tyres were inflated is about 7.0 s.

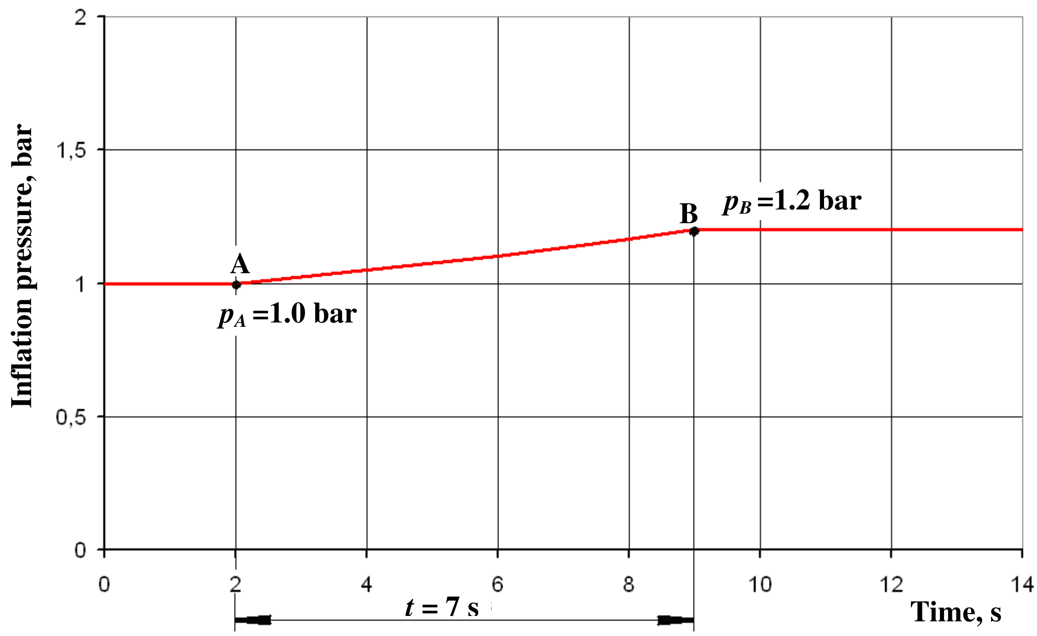

Fig. 4. **Variation in time of pressure when pressure increases from initial value from 1.0 bar to 1.2 bar**

In order to establish the influence of variation interval (range) of pressure on system time of response, the measured data have been centralized in Table 1, where there have been also shown the values of average variation speeds of pressure between the two limits of pressure of pre-established range (lower and upper limit), calculated by means of relation: $v=\Delta p/t$, in kPa·s^{-1} (where Δp is the ranges of pressures variation, in kPa) and t is time duration (in s) consumed for adjusting the pressure between the two values of settle range.

Table 1

Values for experimental measurements determined by calculation when testing the centralized installation of regulating the air pressure in tyres

Pressure adjustment range (bar)	Pressure Difference Δp		One reservoir, V_1 = 40 dm^3		Two reservoirs, V_2 =80 dm^3		Relative growth speed
	bar	kPa	t_1, s	v_1, kPa·s^{-1}	t_2, s	v_2, kPa·s^{-1}	%
0.8...1.0	0.2	20	6. 69	2.98	6.31	3.17	1.06
0.8...1.2	0.4	40	14.90	2.68	13.10	3.05	1.14
0.8...1.4	0.6	60	24.05	2.49	21.13	2.84	1.14
0.8...1.6	0.8	80	35.15	2.27	29.80	2.68	1.18
1.0...1.2	0.2	20	8.20	2.44	7.04	2.84	1.16
1.0...1.4	0.4	40	17.54	2.28	15.07	2.65	1.16
1.0...1.6	0.6	60	28.63	2.10	23.84	2.52	1.20
1.2...1.4	0.2	20	9.43	2.12	8.07	2.48	1.17
1.2...1.6	0.4	40	28.34	1.41	16.50	2.42	1.72
1.4...1.6	0.2	20	11.15	1.79	8.84	2.26	1.26

Conclusions

Analyzing the experimental obtained data regarding the behaviour of the tested central inflation pressure control system in the wheel tyres of the tractor, the following conclusions have been resulted.

1. The period of time of the modification of inflation pressure when tyres are inflated from 0.8 bar to 1.6 bar has lasted for about 30 s when a single compressed air reservoir is connected; from 1.0 bar

to 1.4 bar the period of time has been about 9 s by using a single tank of compressed air; from 1.0 bar to 1.2 bar pressure the period of time has been about 7 s when coupling both reservoirs;
2. The average speeds of pressure variation ranging within the lower and upper regulating values depend on the value of interval and number of air reservoirs used in the installation. For the pressure range of 0.8...1.2 bar speeds of variation of pressure of 2.68 $kPa \cdot s^{-1}$ by using a unique reservoir have been obtained, in comparison with 3.05 $kPa \cdot s^{-1}$ speed when using two reservoirs coupled in parallel. For the interval of pressures of 0.8...1.6 bar pressure variation speeds of 2.27 $kPa \cdot s^{-1}$ when coupling a single reservoir have been obtained, in comparison with 2.68 $kPa \cdot s^{-1}$ speed, in case of using two reservoirs, coupled in parallel.
3. The developed and experimentally tested constructive solution can be applied to agricultural tractors already in use with minimal adaptations, depending on the concrete construction of the tractor, or can be included as an option in tractor axle manufacturing.

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