RESEARCHES ON THE MONITORING OF AIR PRESSURE IN THE TIRES AT ROAD TRANSPORT MEANS
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CERCETARI PRIVIND MONITORIZAREA PRESIUNII AERULUI DIN PNEURI LA MIJLOACELE DE TRANSPORT RUTIERE

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ABSTRACT

Traffic parameters of the road transport means are influenced beside the loads to be transported, the travel speeds, the constructive and functional characteristics by the air pressure in the tires which has a direct impact on the tire tread wear, rolling resistance, compaction, soil compaction and rolling track wear, and finally on the transport operation costs.

This paper presents the research on a transport articulated vehicle made up of an agricultural tractor and a semi-trailer, aiming at continuous monitoring of the transported load in order to determine the optimal air pressure in the tires.

In order to monitor the tire pressure, which is directly influenced by the tire load, an installation was created and placed on the articulated vehicle that continuously measures and monitors, in real time, the transported load, consisting mainly of two force transducers, two force amplifiers, a micro PLC (Programmable logic controller), an operating terminal, and the connection elements between them.

The records made during experiments are managed using software specifically created for these researches.

The experiments were performed at different loads of the semi-trailer, the results obtained from the tests allowing us to determine the authenticity of the software created, on the one hand and the value evolution of the measured parameters, on the other hand.

The determined results allow the operator to make optimal decisions on the air pressure in the tire corresponding to the measured load, also taking into account the nature of the transported load, the type and condition of the rolling track.

REZUMAT

Parametrii de rulare ai mijloacelor de transport rutiere sunt influenţati, pe lângă sarcinile de transportat, vitezele de deplasare, caracteristicile constructive şi funcţionale, şi de presiunea aerului din pneuri, care are impact direct asupra uzurii benzii de rulare a pneurilor, a rezistenţei la rulare, a tasării, compactării solului şi uzurii căii de rulare, şi, în final, asupra cheltuielilor efectuate cu operaţia de transport.

În lucrarea de faţă se prezintă cercetările efectuate asupra unui autotren de transport alcătuit dintr-un tractor şi o semiremorcă agricolă, scopul fiind monitorizarea continuă a sarcinii transportate, în vederea stabilirii presiunii optime a aerului din pneuri

Pentru monitorizarea presiunii din pneuri, care este influenţata în mod direct de sarcina pe pneu, a fost realizată şi amplasată pe autotren o instalaţe care masoară şi monitorizează continuu, în timp real, sarcina transportată, alcatuită în principal din două traductoare de forţă, două amplificatoare de forţă, un micro PLC (Controler logic programabil) , un terminal de operare şi elementele de conexiune între acestea.

Înregistrările efectuate în timpul experimentărilor sunt gestionate cu ajutorul unui soft, special creat pentru aceste cercetări.

Experimentarile s-au efectuat la diferite sarcini de încarcare a semiremorcii, rezultatele obţinute în urma testărilor permiţându-ne să stabilim veridicitatea softului creat, pe de o parte, şi evolutia valorică a parametrilor măsuraţi, pe de altă parte.

Rezultatele determinate permit operatorului să ia decizii optime privind presiunea aerului din pneu, corespunzatoare sarcinii masurate, ţinând seama totodată şi de natura sarcinii transportate, de tipul şi starea căii de rulare.

INTRODUCTION

The main rolling parameters of road transport means are the transported mass (mass of the load + mass of the means of transport) and the travel speed.

Depending on these parameters, the appropriate rolling system and tire type are established, such as air pressure in the tire, with direct implications for tread wear, compaction, soil compaction and rolling track wear, rolling resistance, and finally for the transport operation costs.

The problem of the tires influence in general and of the air pressure in them on the rolling track, regardless of its nature and condition, in particular, has been constantly in the attention of the specialists in the field, at present being published many papers addressing both the theoretical and experimental aspects.

The influence of tire parameters on soil compression and compaction processes has been approached in various theoretical papers in which equations have been developed for the calculation of the contact area of agricultural tires (*Biriş S. Şt., 2012*), the interaction between vehicle wheel and soil and the estimation of soil compaction (*Cardei P., et al., 2007; Popescu S. et al., 2006*), soil degradation as a result of the compression and compaction process (*Diserens E. et al., 2011; Robescu V.O., Elekes C., 2008;*), finite element modeling of tire/terrain interaction (*Xia K., 2011*).

The influence of tire parameters on the traction characteristics was also an aspect studied over time in specialized works of which we mention a traction prediction model for an agricultural tire (*Roşca R., et al., 2014; Roşca R., et al. 2017; Tiwari V.K, et al. 2010*) traction performance simulation on differently textured soils (*Battiato A., Diserens E., 2017*; *Ciuperca R. et al., 2018; Diserens E., 2017; Żebrowski J, 2010;*).

Considering the importance of tires in general and their air pressure in particular on the rolling performance, researchers in the field have also been concerned with the development of practical systems for correcting air pressure in the tire in accordance with the type and condition of the rolling surface (*Dinu, L., 2010*), systems implemented in particular on military vehicles.

Existing rolling systems perform as main functions: supporting the load, rolling, braking and partial shock absorption.

The rolling system which is the subject of the present work is equipped with a load monitoring installation that allows, besides the functions that any existing system performs, to continuously measure the weight of the means of transport. Thus, it provides real-time information on the variation of the weight transferred to the articulated vehicle in the transport situations encountered, as well as on the air pressure in the tires required according to the load transported, the tire type and the rolling conditions.

The information provided by the load monitoring installation can be used both in the stage of design and realization of the means of transport and the choice of the autotractor in the aggregate as well as in the correct choice of the air pressure in the tires or in the monitoring of the means of transport loading operation.

MATERIALS AND METHODS

It is considered a transport articulated vehicle made up of an autotractor and a means of transport, in this case, an agricultural tractor and an agricultural semi-trailer that is placed at rest on a horizontal land.

The action of the semi-trailer on the tractor (Fig. 1) is represented by the bonding forces *R* and F_t. The force R represents the part of the total weight of the semi-trailer G_s that is distributed on the tractor and which contributes to increasing the adhesive weight of the tractor, and F_t is the traction force (*Tecusan N., Ionescu A., 1982; Badescu M. et al., 2014*).

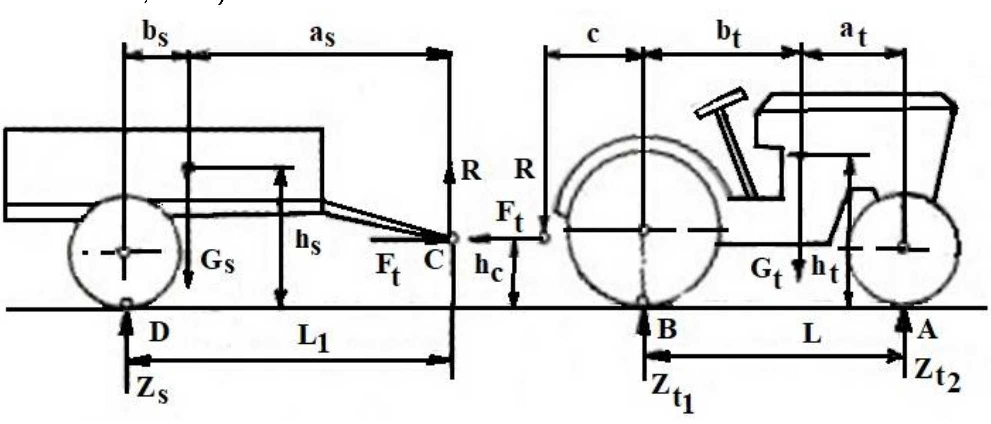

Fig. 1 - Forces and moments acting on the tractor-semi-trailer system

The normal reaction of the ground on the semi-trailer wheels (tire load) $Z_{s,}$ is determined from the momentum equation written in coupling point *C*, according to the equation (1):

$$Z_s \cdot L_1 - G_s \cdot a_s = 0 \tag{1}$$

By grouping the terms, we determine the expression of the Z_s reaction according to the equation (2):

$$Z_s = \frac{G_s \cdot a_s}{L_1} \tag{2}$$

Component *R* is determined with the equation (3):

$$R = G_s - Z_s \tag{3}$$

Substituting the expression of the Z_s reaction with its expression in equation (2), results the expression for the component *R*, according to the equation (4).

$$R = G_s - \frac{G_{s\cdot} \cdot a_s}{L_1} = \frac{G_s(L_1 - a_s)}{L_1} \tag{4}$$

The normal ground reaction on the semi-trailer wheels, Z_s is the size that will be continuously measured and monitored by the monitoring installation, which determines the value of the optimal air pressure in the tires, depending on the tire type, the travel speed, the nature and the condition of the rolling track.

To accomplish this, an operating program was designed, according to the logical schema presented in (Fig. 2).

Input data:

- fixed: tire type; air pressures in the tire recommended by the manufacturer, depending on the load and travel speed; rolling track type.

- variable: load measured by the monitoring installation.

Output data: optimal air pressure in the tire.

Operating mode: Select the travel speed of the means of transport and the rolling track type and, depending on the load measured by the monitoring system, the operating program will show the optimal air pressure in the tire on the display.

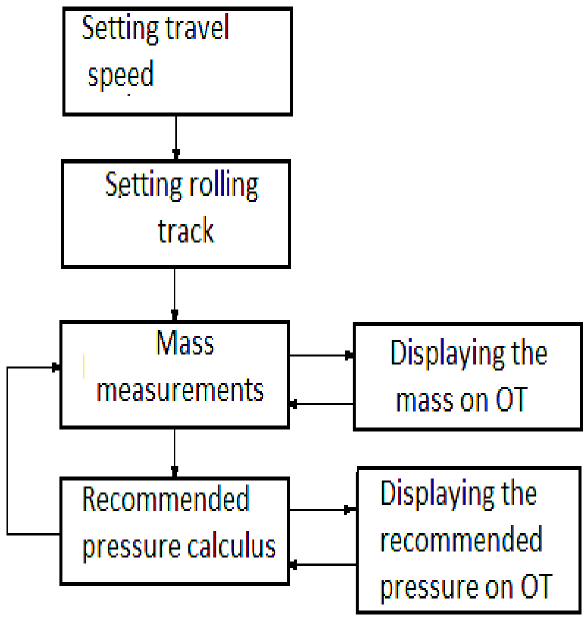

Fig. 2 – Operating program logical schema

OT – Operating terminal

The tests were carried out with a transport articulated vehicle consisting of an autotractor and a means of transport at rest on a horizontal land, in this case a New Holland TD80D agricultural tractor and an agricultural semi-trailer equipped with bogie-type drivetrain (Fig. 3), the semi-trailer being equipped with a load monitoring installation, (Fig. 4).

Fig. 3 – Articulated vehicle: New Holland TD80D agricultural tractor and agricultural semi-trailer

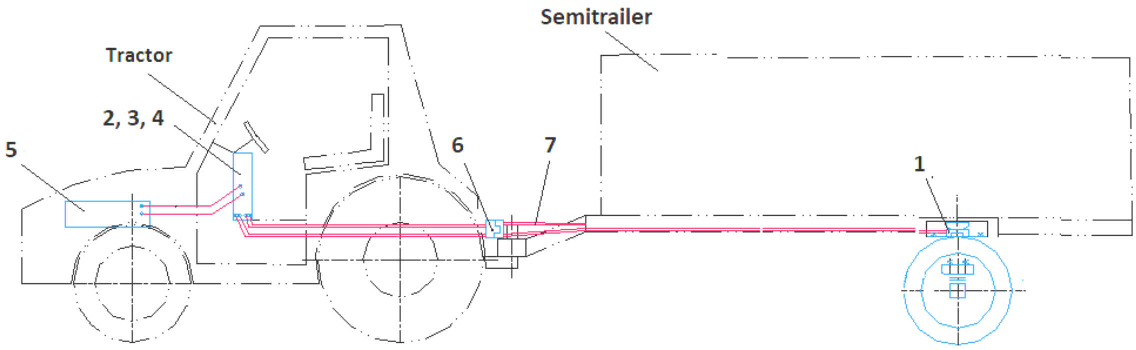

Fig. 4 – Load monitoring installation scheme:

1 – force transducer; 2 – force amplifier; 3 - micro PLC; 4 – operating terminal;
5 - accumulator battery; 6 – double pole fuse; 7 – connecting cables.

In the case of the present paper, we were interested in the forces acting on the semi-trailer, namely $Z_s; R$ based on which the operating program determines the required air pressure in the tires.

Working methodology

In the first stage of the tests, the semi-trailer's own mass G_p, and its distribution Z_p, R_p, were determined by weighting when stationary using the classic system (the weighting machine), and its constructive dimensions were measured and calculated (fig.3), the results being:

- G_p = 4310 daN; Z_p = 3770 daN; R_p = 540 daN.

where: Z_p - distribution of G_p on the semi-trailer axle; R_p - the component of G_s that is transferred to the tractor.

Also, the constructive dimensions of the semi-trailer were measured and calculated as follows:

L_1 = 4.8 m; a_s = 4.2 m; b_s = 0.6 m; h_s = 1.6 m; h_c = 0.45 m

Since the monitoring system transducers were located between the trailer chassis and the top of the rolling system, as shown in (Fig. 4), the weight monitored by them is reduced by the weight of the rolling system, the operating program of the system being realized accordingly.

For these reasons, in order to verify the viability of the previous relations, in the second stage the value of the weight measured by the two transducers was set at 3770/2 = 1885 daN each, the actual load sustained by the tires on the same side of the trailer.

In the third stage, the same parameters were determined by weighing and measurements, with the semi-trailer loaded at G_s = 7250 daN (own weighting + load) for three values of G_s, the determined values being:

- G_s = 7250 daN; Z_s= 6080 daN; R = 1170 daN;

$L_1 = 4.85$ m; $a_s = 4.07$ m; $b_s = 0.78$ m; $h_s = 1.65$ m; $h_c = 0.42$ m

where: Z_s - distribution of G_s on the semi-trailer axle; R_s - the component of G_s that is transferred to the tractor.

In the fourth stage tests were carried out to check the functionality of the monitoring system for three values of G_s (own mass + load), the established values being determined by the existing used load (metal tare weights), respectively:

1. G_{s1} = 7250(4310+2940) daN;
2. G_{s2} = 6830(4310+2520) daN;
3. G_{s3} = 5570(4310+1260) daN.

Equipment used for experiments

- The weighting machine: max. capacity 10t; accuracy class 0.1 – it weights the semi-trailer mass.
- The monitoring installation: placed as shown in (Fig. 4):

- *force transducer*: max. capacity 10 t; protection class IP 68; accuracy class, 0.05; input resistance, ≥ 4350 Ω; high output signal of 2.85mV/V – It converts the mechanical force into an electric signal;

- *force amplifier*: output, ± 10V, 0…10 V and 4…20mA; protection class IP 20. - It amplifies the electrical signal received from the transducer;

- *micro PLC*: no I/O 14; electrical connecting, 24 VDC; digital input, 8; work blocks max. 200. – It processes the signal received;

- *operating terminal*, main characteristics: power terminal, 24 VDC; number of touch keys, maximum 50 keys/screen; user memory 512 kB or less - It displays the results obtained and represents the operator interface.

RESULTS

The results determined by the monitoring system are presented in Table 1.

Table 1

Values determined for Z_s and R

Test no.	Parameter determined	Values			
		Determined by the monitoring system [daN]	Determined by weighting machine [daN]	Difference [daN]	Deviation [%]
1	G_s [daN]	5558	5570	-12	- 0.2
	Z_s [daN]	4854	4860	-6	- 0.1
	R [daN]	704	710	-6	- 0.8
2	G_s [daN]	6840	6830	+10	0.1
	Z_s [daN]	5975	5968	+7	0.1
	R [daN]	865„	862	+7	0.3
3	G_s [daN]	7261	7250	+11	0.2
	Z_s [daN]	6082	6080	+2	0
	R [daN]	1179	1170	+9	0.8

It can be noticed that the differences between the values determined by the classic system and those by the monitoring system were insignificant, so the monitoring installation is functioning correctly, the deviations having values that fall within the constructive error margin of the used measuring equipment.

Using the data specified in Table 1, the operating program determined the optimal tire pressures p_a, in accordance with the rolling track type and the pre-set travel speeds, the results being shown in Table 2, for the tire equipped with the 16.00-20/12PR outer cover.

Table 2

Values determined for the air pressure in the tire

Test no.	Parameter determined	Values determined by the monitoring system		
		Speed = 15 km/h Ground road	Speed = 30 km/h Concrete road	Speed = 40 km/h Highway
1	G_s [daN]	5558	5558	5558
	p_a [bar]	1,25	2	2,25
2	G_s [daN]	6840	6840	6840
	p_a [bar]	1,5	2,25	2,5
3	G_s [daN]	7261	7261	7261
	p_a [bar]	1,75	2,5	2,75

The operating program interface is presented in (Fig. 5).

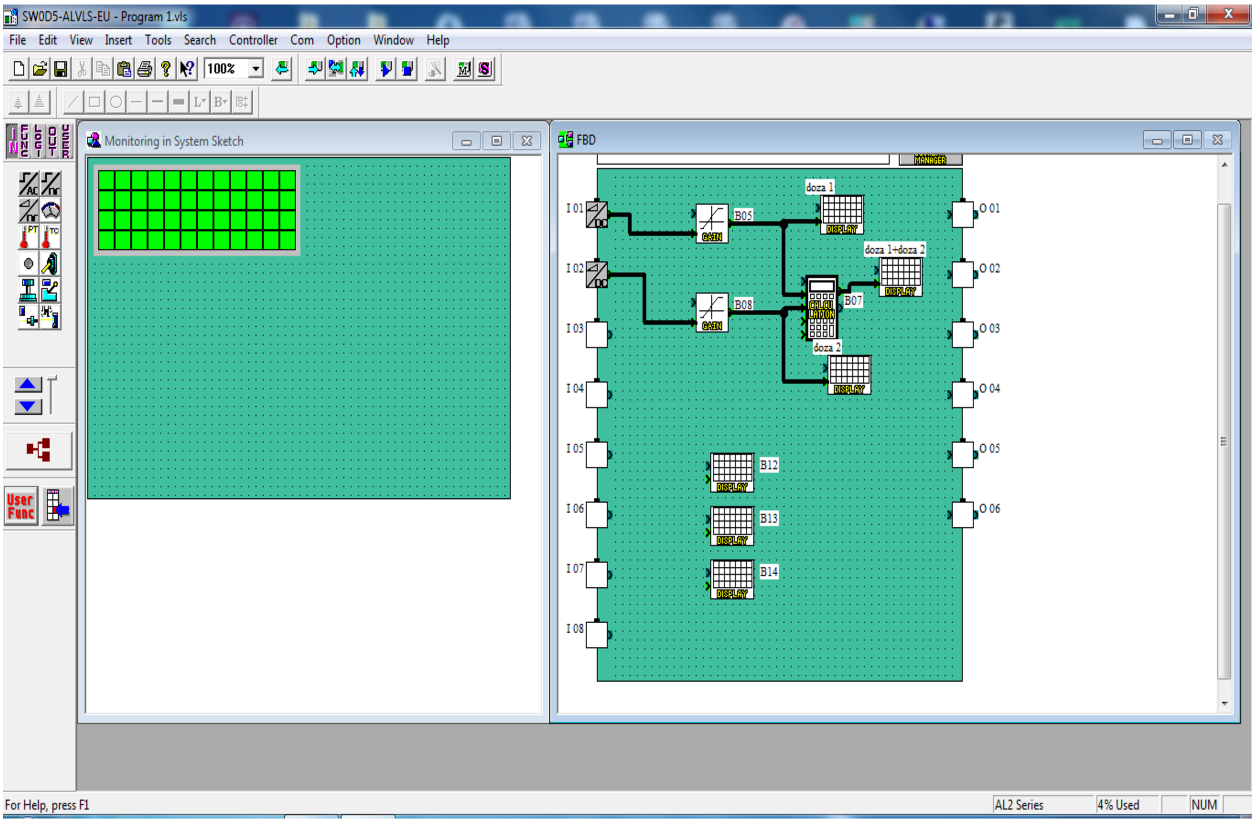

Fig. 5 – The operating program interface

The variation of the values of the components Z_s and R at the same amount of G_s depends on the position of load placement in the trailer to the axis of the driving system. A placement more toward the tractor could lead to a situation in which the value of R exceeds the value of the maximum permissible load on the tractor from the articulated vehicle, as declared by the manufacturer, which can be dangerous.

The information provided by the monitoring system, on the operating terminal, can avoid this situation because the operator has information about the value of R reconnected during loading of the trailer and can coordinate the proper placement of the load in the trailer.

For the experiments carried out in his work, with articulated vehicle, the variation of R according to the position of the load on the trailer, determined by the cart a_s, is presented in (Fig. 6), in which is marked the maximum value of R, allowed by the tractor from the articulated vehicle.

Experiments have been carried out for the G_s = 7261 daN.

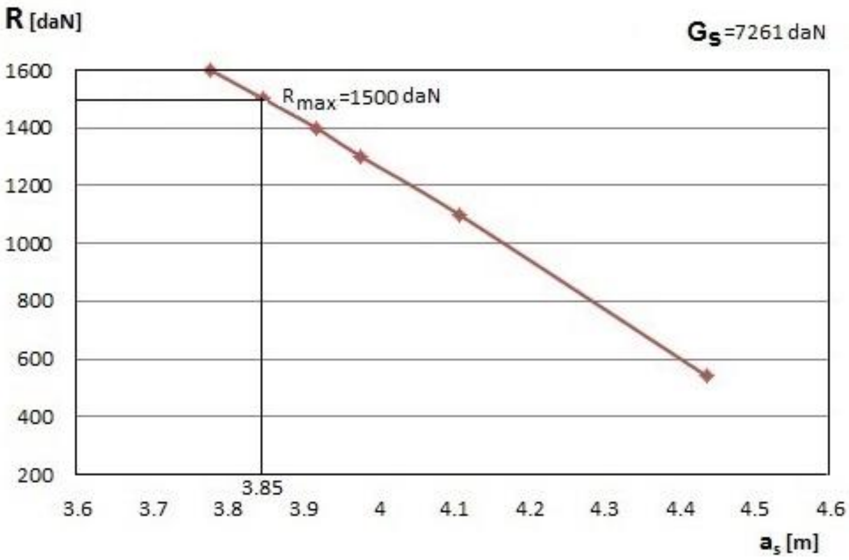

Fig. 6 – The variation of the component R depending on the position of the load on the trailer Articulated vehicle: New Holland TD80D agricultural tractor and agricultural semi-trailer

CONCLUSIONS

1. The rolling system which was the subject of the present paper is equipped with a load monitoring installation that performs real-time, continuous measurement of the weight sustained by the trailer rolling system and its variation as a result of the weight transferred to the tractor;

2. The values measured in the experiments for the trailer weight G_s, the soil reaction to the trailer rolling system Z_s and the weight transfer from the semi-trailer to the tractor *R* was very close to those determined theoretically with the mathematical relations, the deviations calculated as the ratio of the theoretically calculated value to the value measured in experiments ranging between 0.1 - 0.8%, values that fall within the constructive error margin of the measuring equipment;

3. The operating program that was realized is working properly, providing the operator with information regarding the load on the rolling system and the optimal air pressure in the tires;

4. Continuous, real-time monitoring of the transported loads provides useful information to the operator so that he can optimally control the articulated vehicle rolling parameters by adapting the air pressure in the tires according to the transported load, the rolling track type and the travel speed, thus reducing the imminent dangers that may occur during the transport operation and ensuring an efficient transport.

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