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EQUIPMENT AND METHODOLOGY FOR EXPERIMENTAL RESEARCH OF THE DYNAMIC AND ENERGETIC OF THE HIGH POWER AGRICULTURAL TRACTORS OF IN AGGREGATE WITH TILLAGE MACHINE SYSTEMS

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Abstract: *The paper presents the construction and location of the transducers and sensors for determining the traction force and vertical pressure force on rear three points hitch of the tractor on the high powered tractors in aggregate with tillage machine For determining the tractor traction power a supplementary wheel for measuring the real speed of the tractor is used. For measuring the torque and angular speed of the tractor PTO shaft a torque and angular speed transducer was performed, mounted between tractor PTO shaft and the driving cardan axle of machine. For determining the distribution of the tractor traction power on the two driving axles a torque and angular speed transducer was performed, mounted on the cardan transmissions of driving axles.Transducers and sensors, which are appropriate for the electrical measurement of the above mentioned parameters, were placed on the tractor - machine system, while the data recording and acquisition equipment was placed in the tractor cabin.*
This equipment is enabling to simultaneous measurement of the following parameters: connecting forces between tractor and machine, the torque transmitted to machines through the tractor power take-off (PTO) shaft and the torques transmitted to tractor driving axles.
Keywords *agricultural tractor, agriculture machine, dynamic and energetic of tractor-machine system, experimental research, measurement installation, data processing.*

1. INTRODUCTION

The experimental research of the tractor- tillage machine system has as role the determining the characteristic parameters the dynamic and energetic behaviour of the system which consisted of four-wheel drive tractor type T 195 and the combined seedbed preparation devices type ACPG-3 (both made in Romania) in different work conditions.
The experimental research had as purpose the determination of the following main parameters: forces which act on the rear three points hitch of the tractor (traction force and pressing force between tractor and implement); torsion moments transmitted to the drive axles of the tractor; the torsion moments transmitted to the machine through the tractor PTO axle; the real working (travelling) speed of the tractor; slip of the rear axle tires of the tractor. On the base of these parameters it can determinate (calculated) the tractor power consumption for traction (drawbar power) and driving trough the PTO shaft of coupled machines.
The determination of followed mechanical parameters (forces, torsion moments, rotation speeds, travelling speed) was made through electric (electronics) methods which presents advantage of a simple and fast assemblage of sensors, transducers and equipment and assuring of a high precision of measuring, and allows the possibility for simultaneous data acquisition measured parameters. In figure 1 is presented the location scheme of transducers and sensors to carry out the experimental researches of the system consist from the tractor type T 195 and the combined seedbed preparation devices type ACPG-3, which is a carried tillage (with no supporting wheels), entrained simultaneously through PTO shaft of the tractor

2. MATERIAL AND METHODS

The measurement of linking forces between tractor and the tillage machine (the resistance force to traction of machine and the presing force exerted by the machine) was performed with a intermediat frame with tensometric transducers (tensometric frame) presented in figure 2.

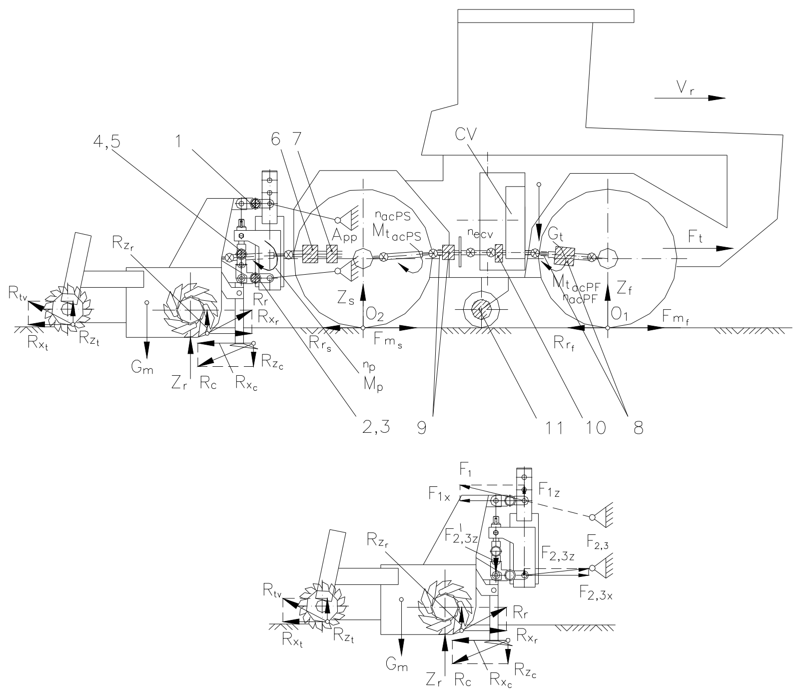

Figure 1. Location scheme of transducers and sensors on the tractor- tillage machine system (a) and the forces actingon rear three points hitch of the tractor (b):
1, 2, 3 – transducers for measuring of traction forces between tractor and machine (mounted on the three points hitch of the tractor); 4,5 – transducers for measuring pressing forces between tractor and machine; 6 - transducer for measuring moment of torsion on PTO shaft; 8,9 - transducers for measuring of torsion moments of cardan from driven axle of the tractor; 7, - transducers for measuring of rotations speeds of PTO shaft, 10 - transducers for measuring of rotations speeds of cardan axles of the tractor 11 - transducers for measuring of rotations speed of the fifth wheel

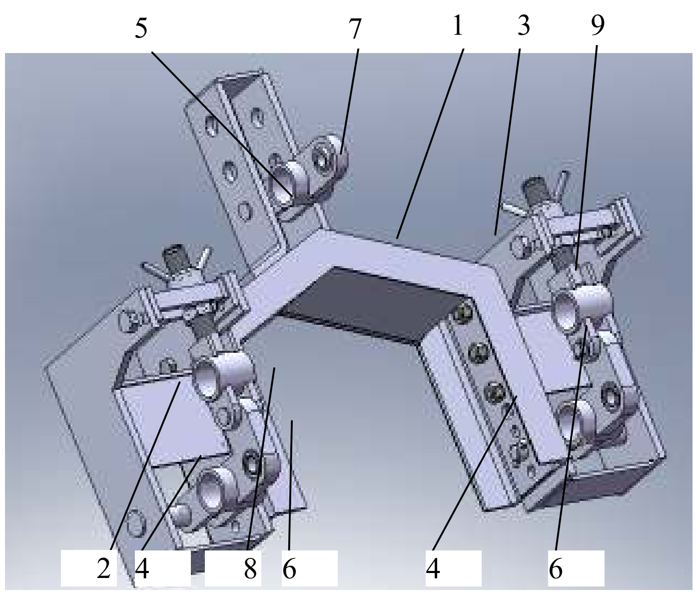

Figure 2. Intermediate frame with tensometric rings for forces measurament of machine traction force:
1-central frame; 2,3-lateral frame; 4- lateral pin; 5- central pin; 6- horizontal lateral supports strain gauges; 7- central supports strain gauges; 8-pin; 9- vertical lateral supports strain gauges.

The device is made of 3 frames (central 1 and sides 2, 3) and five strain gauges supports which can be assembled in three positions, making it possible to couple it to the suspension mechanisms at 3 hitch points and to the coupling devices of the agriculture machine. The frame is coupled to the rear three points hitch of the tractor by coupling the side and central links of the tractor to the side bolts 4 and central bolts 5 on the frame. Side bolts 4 and central bolt 5 are fixed to the horizontal lateral supports strain gauges 6 and central suport strain gauges 7 which are made of clamping plates to the frame bolts, plates with incorporated ball joint for bolts coupling to the coupling devices of agriculture machine and elastic rings on which tensometric forces transducers are mounted. The side strain gauges supports 6 are connected through bolts 8 to vertical strain gauges supports 9 made of clamping plates, threaded rod and elastic ring. Through the threaded rod of vertical strain gauges supports the parallelism position of side strain gauges supports to the soil and the position of the agricultural machine to the tractor are adjusted.
Because of sides and central frames is adjusted parallel with soil, it can measure with tensometric electroresistive transducers (TER) rings mounted on the two lower (lateral) and the upper (central) links of the rear three points hitch of the tractor, which measure the traction forces (drawbar pull) of the tractor F_{2x}, F_{3x}, and F_{1x} (Fig.3, a).The strain gauges of the of the tensometric rings were mounted on a strain gauge Wheathstone bridge (Fig. 3, b).

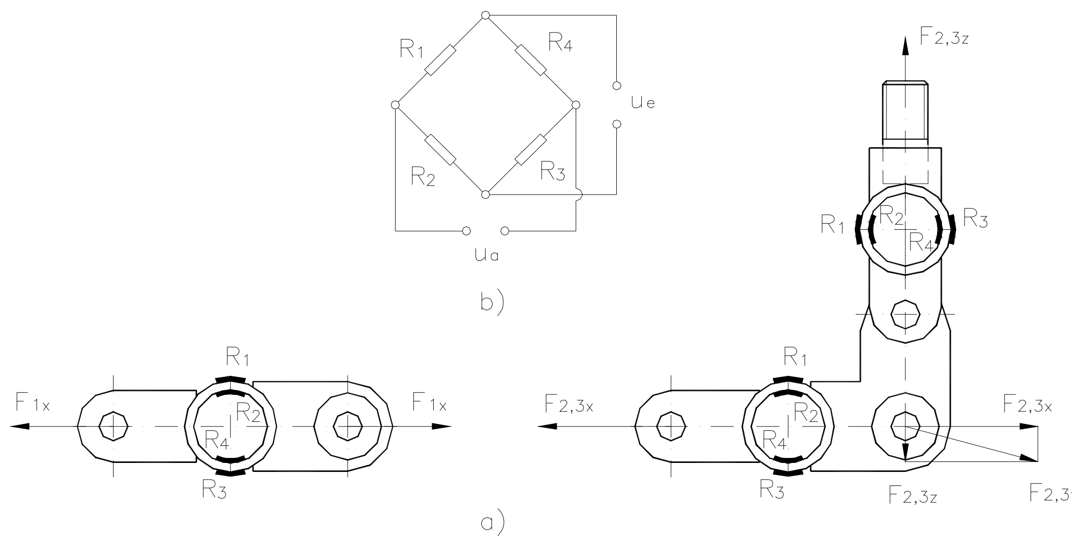

Figure 8. Scheme of tensometric rings for forces measurement from links of the rear three points hitch of the tractor : a-the location of trade strain gauges on the tensometric ring; b - mounting scheme of strain gauge on a Wheathstone bridge

For measuring of torsion moments transmited from cardan axles of tractor transmission and from PTO shaft is used method based on electro-resistive transducers (TER). To perform measuring device based on this method, on measuring axle (fig. 4) are applied four transducers (strain gauge), R_1, R_2, R_3, R_4: two transducers are canting to the 45^0 in a direction (R_1, R_3) and the other two (R_2, R_4), canting to 45^0 in other direction (normal on the first). Because of this position of the strain gauges and the through their connecting into the Wheatstone complete bridge is performed a maximum response of measuring, but a compensation of error because of bending (compassing or bending pressure) and differences of temperature.
The connecting of transducers (strain gauge) into Wheatstone bridge to the feeding installation (power-supply) and to the measuring installation (measuring tension) is performed with the help of a collector with contacts sliders, made up from rotation pieces A, B, C and D (mounted on the axle) and the commutation brushes a, b, c and d (mounted on a fixed support).
For measuring of the rotation speed of the cardan axles of the PTO shaft and the fifth wheel axle rotation speed a variable reluctance sensors were used. The rotation speed of the cardan axles for drive of the two tractor axles receive rotation moving from the gear tractor distribution gearbox.
For measuring of real travelling speed of the tractor a supplementary wheel (fifth wheel) was mounted lateral on the tractors (fig.5).The wheel performing turning of a travel speed in angular speed, measured with a sensor of rotation with responses with electromagnet sensor 6. Measuring device is made up from support 1 (which is fixed on tractor) and fork 2, in which is mounted the tyre wheel 4. The forked is fixed on the support 1 trough the cardan joint 3. The electromagnetic impulses are induced by the dinted steel disc 5. The spring 7 press the wheel 4 on the soil during the travel to assure the permanent contact with soil and rolling of this without slip. The dynamic operating range of wheel tyre 4 has constant and known value r_s.

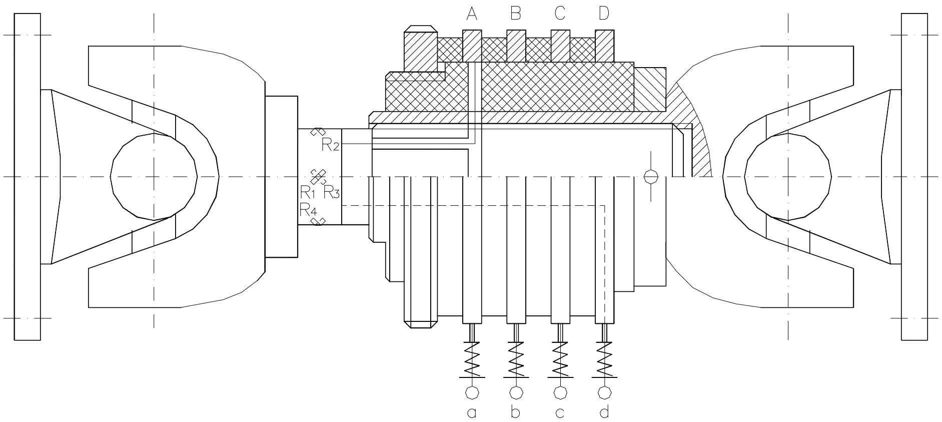

Figure 4. Location scheme of transducers and of collectors with contact sliders for measuring of torsion moment transmitted of the cardan axles and PTO shaft

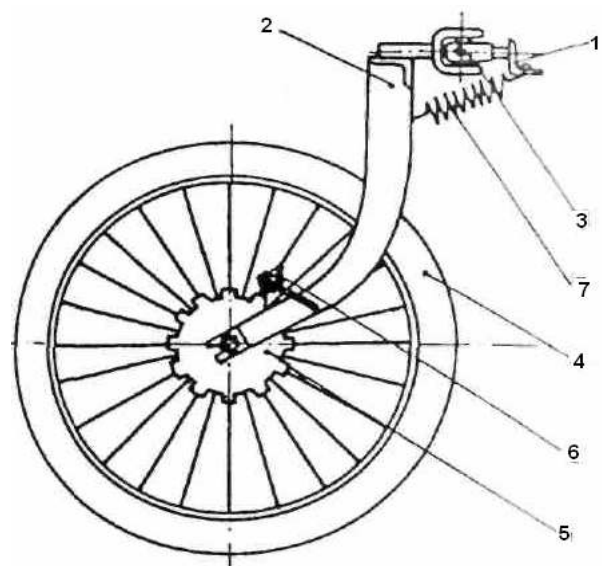

Figure 5. The constructive diagram of a device (fifth wheel) for determination of the travelling speed of the tractor

The space (distance) S_r passed by the tractor- machine system during the travel is determined by relationship:

$$S_r = \frac{2\pi \ r_s N_{rs}}{Z_{rs}} \ \text{[m]} \tag{1}$$

and the linear speed (work speed) of tractor *v,* is calculated with relationship:

$$v = \frac{2\pi . r_s N_{rs}}{Z_{rs} t} \ \text{[m/s]}, \tag{2}$$

where: r_s is the dynamic operating radius of the wheel, in m; N_{rs} – the number of impulses of transducer (sensor) of the wheel; Z_{rs}- number of indentations of disc transducer: *t*- time, in s..

The dynamic and cinematic experimental data transmitted by the sensors and transducers were collected according to the measurement linkage of figure 6. For this purpose a DAO 2400 system (manufactured by Microstar Laboratories USA) was used, available at the National Institute for Agricultural Machines (INMA) of Bucharest/Romania. This system has 16 analogical inputs, 16 digital outputs and a testing frequency of 120 kHz. A 3B 18/3820 ANALOG

DEVICES type amplifier ensured amplification of the quantities. The energy source was a lead plate battery and 12 V voltages. The data collection software allowed the filtration of the signals obtained by the DMS sensors and transducers, as well as determination of the minimum, maximum and means values of the signal. The DAP system is installed on a 486 DX 4 LAPTOP containing the data collection software, using the specific DALP language.

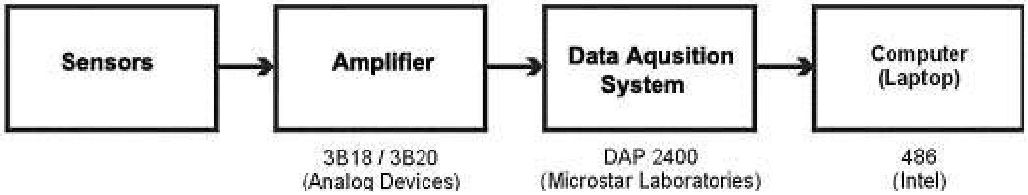

Figure 6. Data collection and processing equipment diagram

In figure 7 it is presented the block diagram for collection, acquisition and data processing by experimental researches (notations significance for measured parameters are those from Fig. 1).

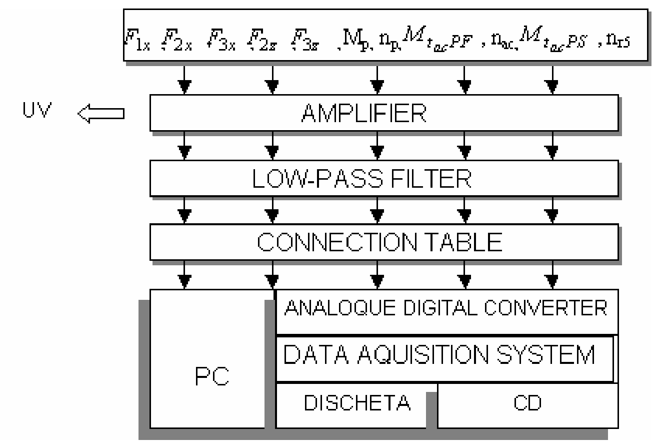

Figure 7. Block diagram of the system for collection, acquisition and data processing

The following graphs present the time variation curves of traction force of the tractor (Fig. 6) and torsion moments at cardan axle driving the front axle (Fig. 9) and PTO shaft (Fig. 10) at a tractor average traveling speed of 5.54km/h

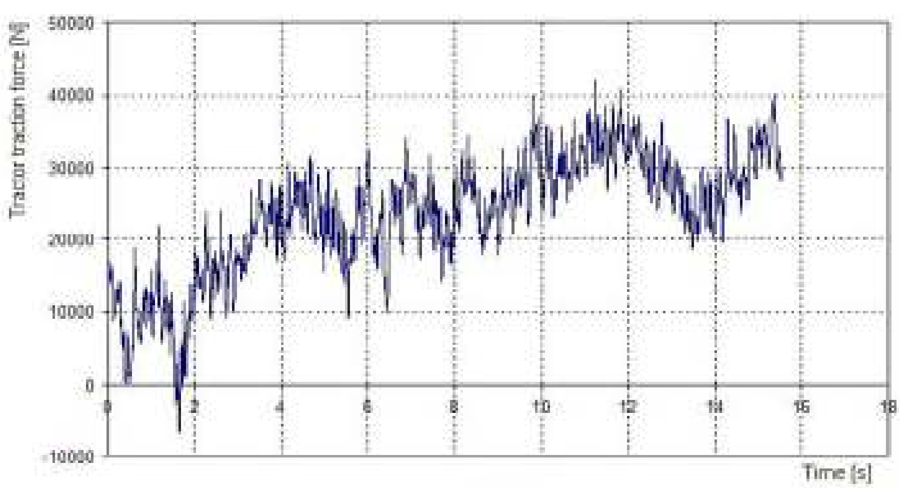

Figure 8. Time variation of the tractor traction force (resistance force of the tillage) at tractor speed of 5.54km/h

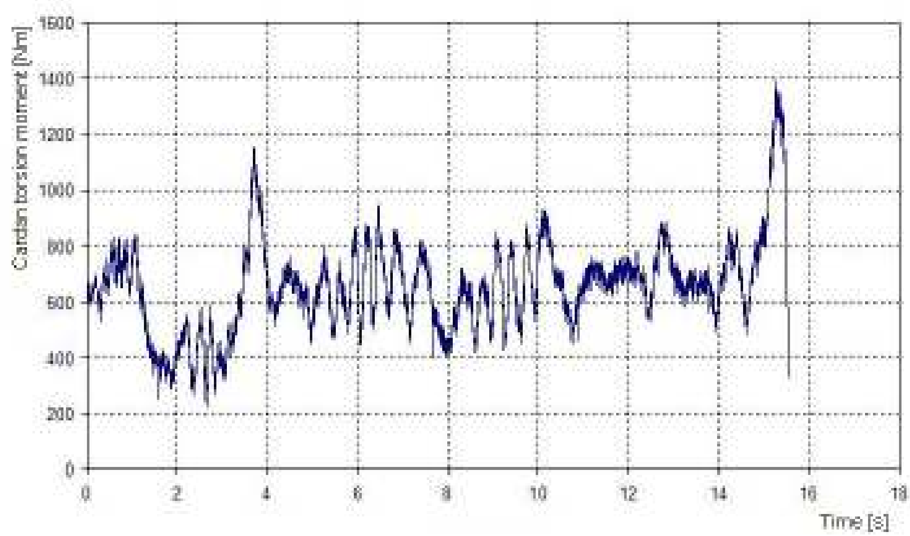

Figure 9. Time variation of torsion moment at cardan axle driving the front axle at a tractor average speed of 5.54km/h

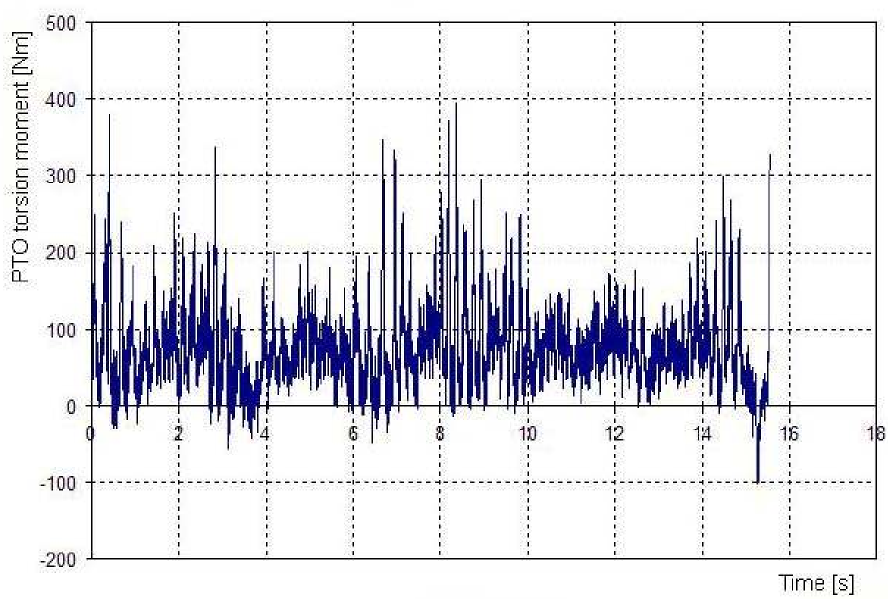

Figure 10. Time variation of moment of torsion at PTO shaft to operate the coupled machine at an average number of rotation speed of 706 rot/min and at a tractor average speed of 5.54km/h

3. CONCLUSIONS:

- By means of tensile frame mounted on three point-suspension system of tractor, the resistence force of agricultural machines coupled to tractor is controlled.
- By measuring the tractor real displacement speed by the device endowed with additional wheel (the 5th wheel) and of force of resistence at traction of agricultural machines coupled to tractor, the power consumed for agricultural machines trailing can be determined.
- By measuring the moment of torsion and PTO's number of speeds performed with tensile couple device we can calculate the power consumed when the carried machines are driven from PTO.
- By measuring the torsion moment and number of speeds of cardan axle which operates the rear axle we can determine the distribution of tractor traction force on each tractor axle.
- By measuring the tractor real displacement speed (with 5th wheel device) and tractor, theoretical speed (by means of speed of tractor's wheels) we are able to determine the tractor skidding and, implicitely the power consumed by skidding.

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