DETERMINING OF DRIVETRAIN SYSTEM SKID STEER 6X6 WHEELED ROBOT LOAD

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ABSTRACT

This paper presents the results of 3 tons skid steer 6x6 wheel robot drive system field tests. The aim of the investigation was verification of assumed data for drivetrain diesain and forces identification in the drivetrain system during maneuvering and crossing obstacles. Robot has hydraulics drive system with motors in the wheels and hydraulic suspension system. The neded drive torque on wheels was determined by pressure measurnig on motors.

KEYWORDS

Skid-steer vehicle, UGV, Robot, Obstacle, Turning and roling resistance, 6x6 vehicle, Hydrostatic drive

INTRODUCTION

To carry out tasks in hazardous zones heavy construction robots weighing 3-5 t are increasingly used - Figure 1-2 - built on a mini-machines (Moorhead, 2010).. Their operating possibilities are, however, limited by the relatively low longitudinal and lateral stability and low speeds. As a result, lifting capacity of these machines weighing about 3 tons is less than 600-700 kg, maximum speed for mini-excavators is typically 3-4 km / h, and maximum speed for mini-loaders does not exceed 10 km/h. Their ability to work on slopes and the ability to overcome obstacles is also limited. To provide better efficiency for work in difficult terrain requires the ability to:

- Lift the load up to 1500 kg (weight of Euro-pallets);
- Develop the speed up 10km/h in terrain;
- Develop the speed up to 30 km/h on roads;
- Move on slopes about side slope at 30%;
- Climb slopes at grade of 60%;
- High maneuverability.

Figure 1 - Robot LC-50 built on the basis of Caterpillar skid-steer loader

Figure 2 - Robot Scorpion built on the basis of Bobcat mini-excavator

To meet this requirement in the Military University of Technology the concept of heavy wheeled robot was developed and test-bed was built in purpose for its verification - Figure 3. To provide high stability of the longitudinal and lifting capacity and the ability to overcome obstacles udercariage 6x6 chassis and skid steer system for high maneuverability were adopted. The robot has a mass of 3000 kg, 2 x 1.1m wheelbase, track of wheels equal to 1.75 m and has two cooperating attachments: manipulator and loader's attachment with quick-coupling.

To provide a high ability to overcome obstacles a special hydraulic suspension system was designed that provides a high displacement of wheels, an equable distribution of pressure on the ground and the possibility of stiffening during operating on attachments to improve stability (Muszyński, 2011).

The hydrostatic drive system was used to drive a robot, its scheme is shown in Figure 4. It consists of two independently controlled axial piston pomps, six hydraulic fix displacement gerotor motors mounted directly in the wheels and two gear flow dividers. Since the design of the vehicle (wheel base of the vehicle is relatively large in relation to its width) differs from the typical steering resistance, solutions were difficult to calculate (Commellas, 2013 ; Li, 2011,2012). Therefore, the design of the propulsion system driving assumes that the nominal pressure of hydraulic motors should provide the wheels break grip on every surface, taking into an account, the weight put on the wheel while driving uphill. As a result, in the designed robot, at a pressure of 320 bar, traction force is equal to its weight.

The aim of this study was to verify the assumptions and recognition of loads that can be found in such driving system during maneuverability and overcoming obstacles.

Figure 3 - Test-bed of MUT heavy wheeled robot “Marek”

METHODS

An off-road track, consisting of, among others, the slope with inclinations at angles: $\alpha_1 = 18° = 30\%$, $\alpha_2 = 23° = 40\%$, and $\alpha_3 = 30° = 60\%$, the trench with depth of 0.5 m, the soil embankment with height of 1 m, and grounds with different capacity, was prepared in order to assess the ability to overcome obstacles and to identify the loads. Since the robot is equipped with a hydrostatic drive system to determine the traffic loads is relatively easy by measuring the differential pressure in the system. For this purpose, six pressure sensors were installed near the inlet and outlet ports of motors on the same side - in accordance with Table 1. Comparison of the registered pressure differences to the nominal pressure of 320 bar will let to determine the size of the movement resistance in relation to the weight of the robot.

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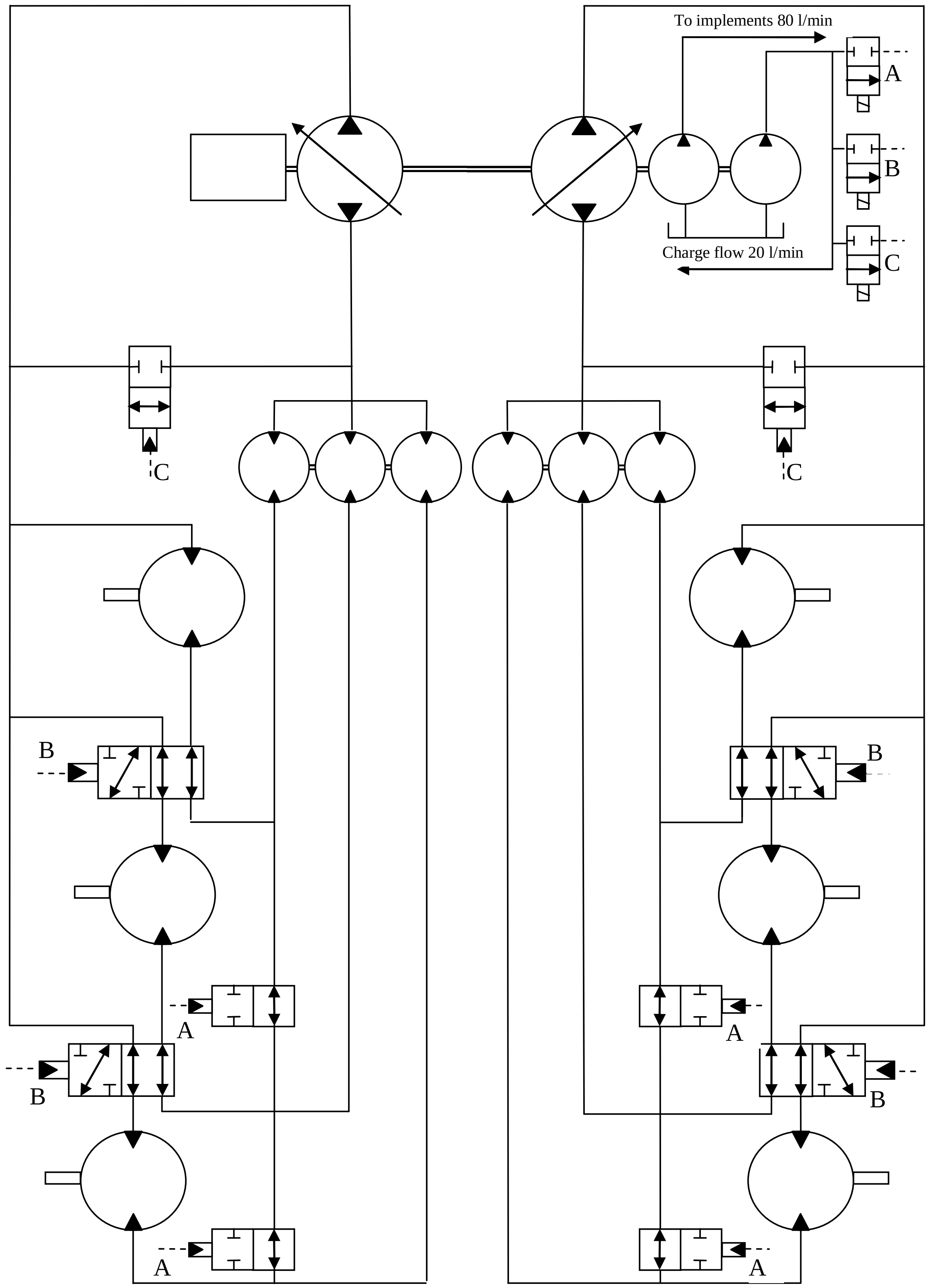

Figure 4 - Simplified hydraulic circuit diagram of robot „Marek” drivetrain system

For measurement , it was used, as follows:

- Pressure sensors KOBOLD SEN-8700 in high pressure line – measurement range 0 – 600 bar, in return line – measurement range 0 – 400 bar and accuracy class 0,5;
- data acquisition system IO Tech Personal DAQ 3005;
- laptop which recorded the measurements.

Table 1 - Accepted labels pressure sensors

SENSOR POSITION		ACCEPTED LABELS
Front wheel	High pressure line	S5
	Return line	S6
Central wheel	High pressure line	S3
	Return line	S4
Rear wheel	High pressure line	S1
	Return line	S2

To in – depth study of loads the program of the study included:

- Driving straight on various terrain;
- Driving slalom correcting the direction slightly on various terrain;
- Turn in place;
- Crossing the ditch;
- Overcoming the shaft.

RESULTS AND DISCUTION

First the designation of own hydraulic resistance tests were made to determine the actual resistance of the robot while driving on the test track at the Department of Mechanical Engineering. The test was performed when the robot was completely lifted (no wheel contact with the ground). The test was based on progressive increase of the rotation speed and pressure values measured at both, the high pressure line (S1, S3, S5) and the return line (S2, S4, S6). Timing changes in the pressure for the individual lines during the test are shown in Figures 5.

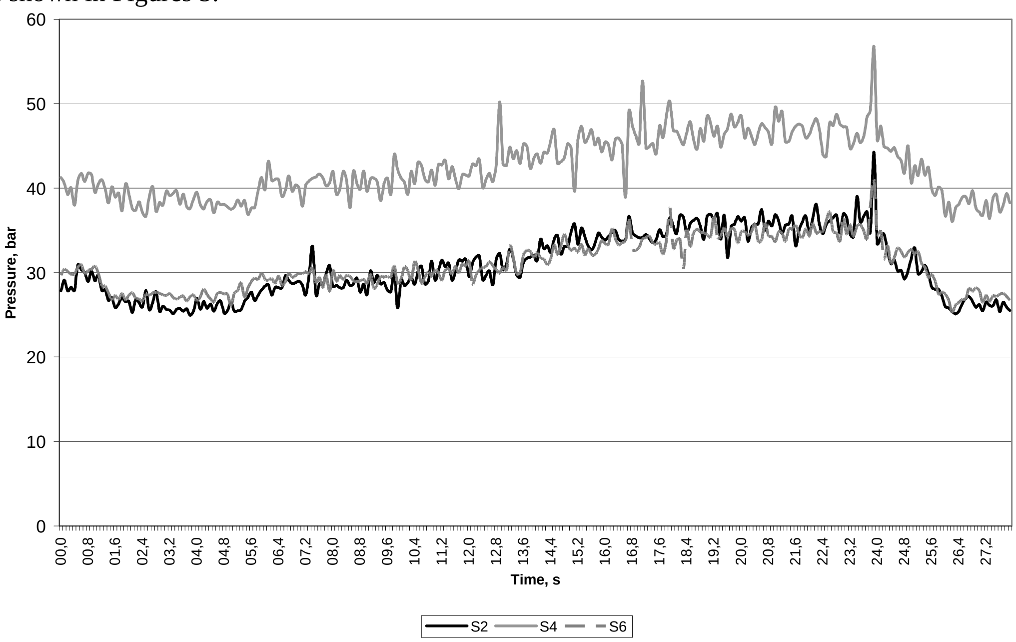

Figure 5 - Sample courses of pressure in high pressure lines of hydraulic motors during testing the own resistance in hydraulic system

The pressure of unloaded drive system prevailing power lines (S1 and S3) and hydraulic motors of central and rear wheels, when the wheels do not turn, does not exceed 30 bar (figure 5), while the pressure of line that supplies the motor of the front wheel (S5) is a bit higher and is about 35 bar. However, after putting the wheels of the robot in motion, pressure on lines becomes steady and grow to a maximum of 45 bar and in pulses to about 55 bar. The pressure in the outlines of unloaded hydrostatic drive system after putting the wheels in motion increases slightly by about 5 bar to 35 bar (S2, S6) and up to 45 bar (S4). The difference in pressure between the motor center wheel (S3, S4), and the other wheels is due to structural reasons (using smaller diameter wires).

The resistance of motion has been tested after determining the resistance of its own driving system The loads measurements of hydrostatic drive system were done at about 7 km/h.When driving straight, it was found that the lowest resistance occurs when driving on surfaces with good bearing capacity (Figure 6). Pressure drops in hydraulic motors are at the level of 40 bar (high pressure line about 70 bar, return line about 30 bar). Roling resistance were about 12% of the force of gravity. While moving on asphalt surfaces, due to low directional stiffness of front rockers and large forces necessary to induce wheel slip, the resistance was much higher and amounted to about 20% of the force of gravity. The greatest resistance up to 25-30% of the force of gravity was recorded at the wetland area of the low capacity (CI = 150 kPa) - Figure 7.

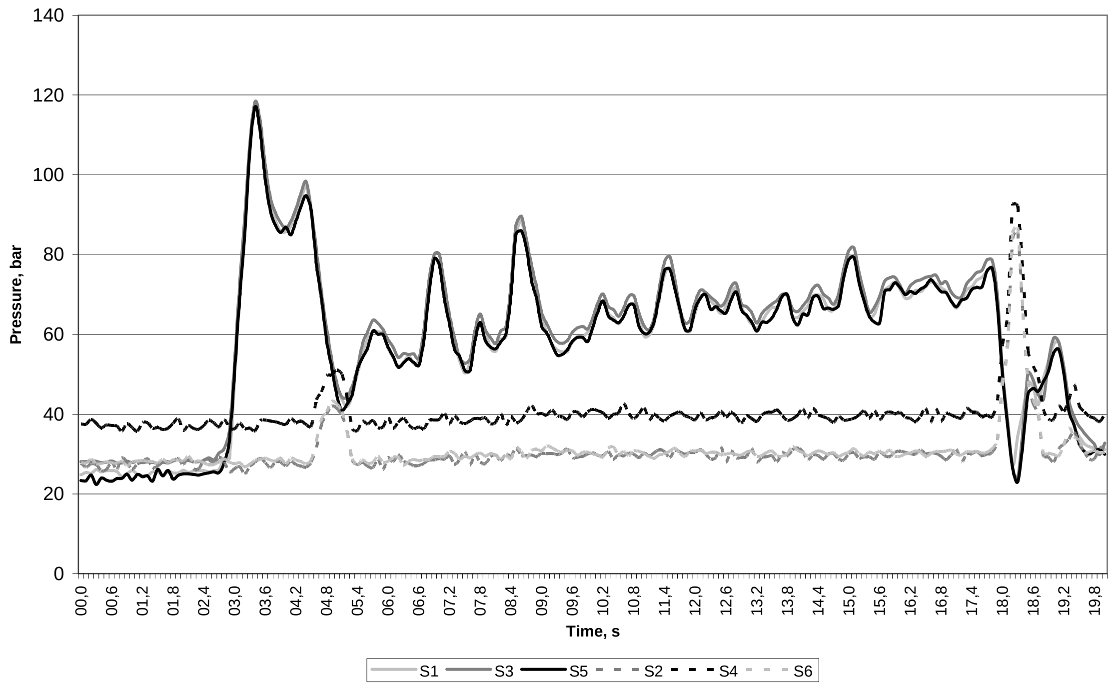

Figure 6 - Courses of pressure during driving straight on the ground with a capacity of CI = 280 kPa

The research of hydrostatic drive system, while performing a turn, was carried out in the course of driving a slalom (radius 20 m) on the asphalt road and the ground with a capacity of CI = 280 kPa. The results indicate that the turn performance done on the asphalt road (Figure 8) causes roling resistance at 50% of the force of gravity, while maneuvering on the ground is much easier and it causes the resistance at the level of 35% of gravity (Figure 9).

Significantly higher resistance was recorded when performing a rotation turn in the place and trying to drive the wheels in opposite directions - the resistance on the asphalt surface (Figure 10) were between 65-70% of the force of gravity and were equal to tire grip. No less values recorded during a turn on the ground – Figure 11. The resistance of creation and movement of a pile of ground during a turn - Figure 12 -influenced their value significantly.

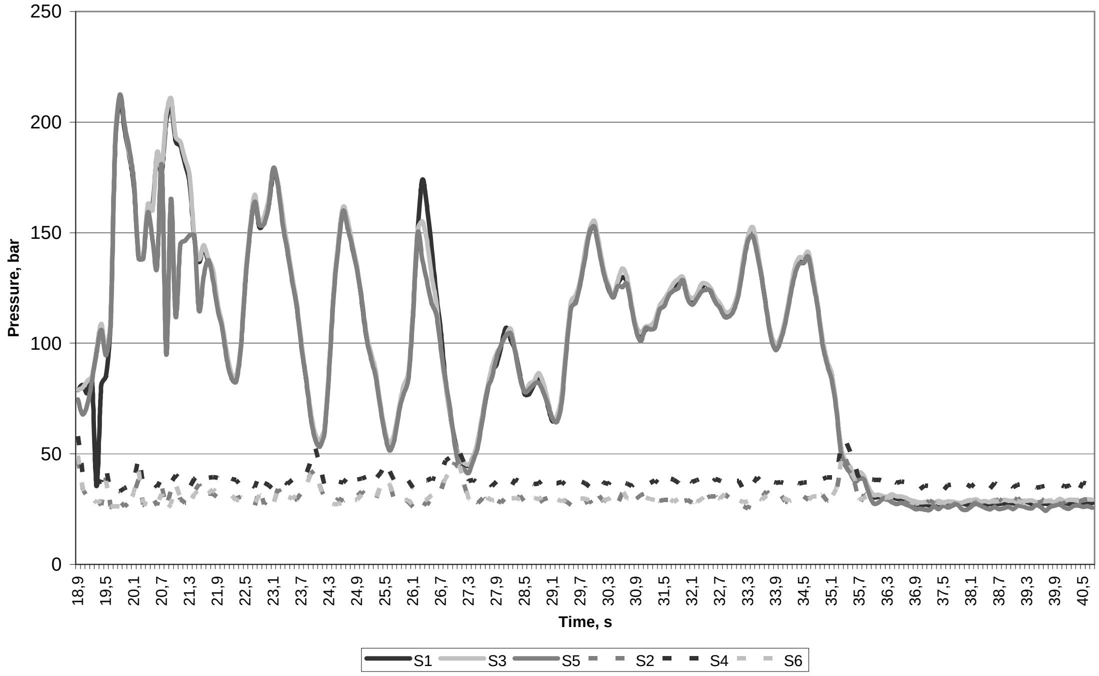

Figure 7 - Courses of pressure during driving straight on the ground with a capacity of CI = 150 kPa

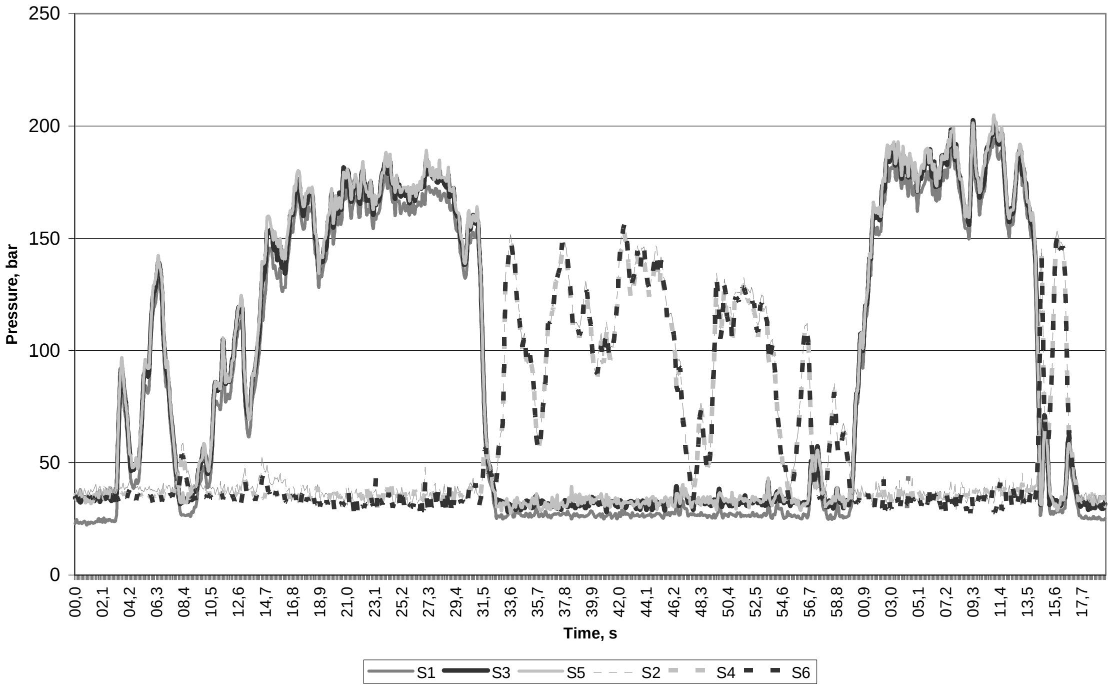

Fig.8. Timing changes in pressure in in-lines and out-lines of hydraulic motors of robot driving slalom on the asphalt road

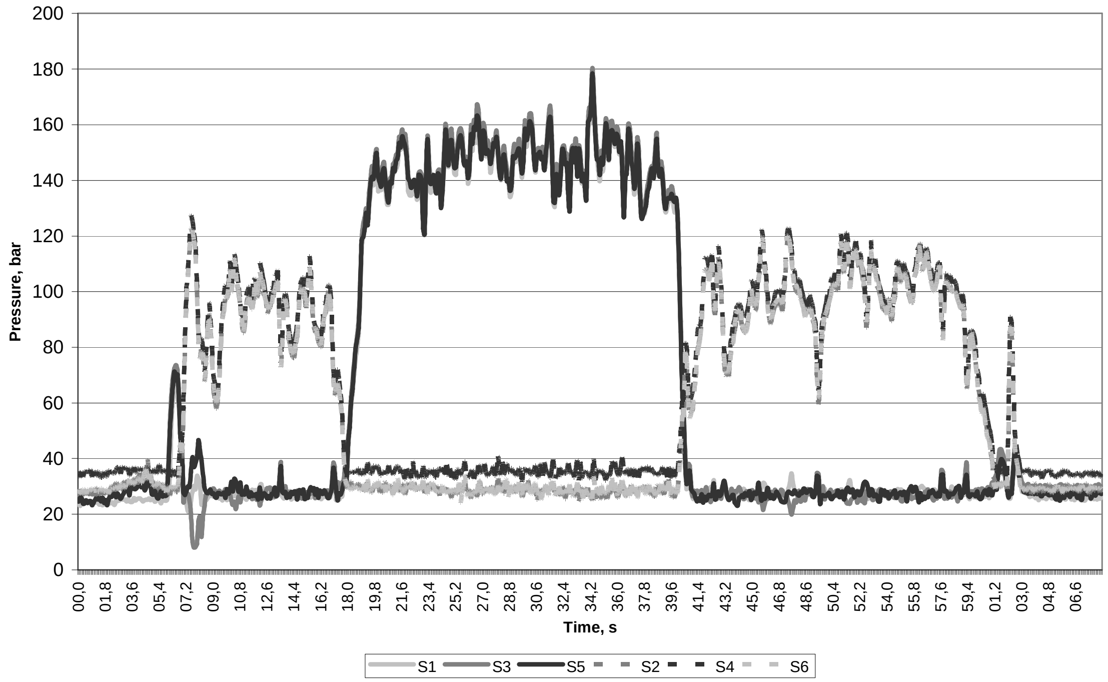

Fig.9. Timing changes in pressure in in-lines and out-lines of hydraulic motors of robot driving slalom on the ground with a capacity of CI = 280 kPa

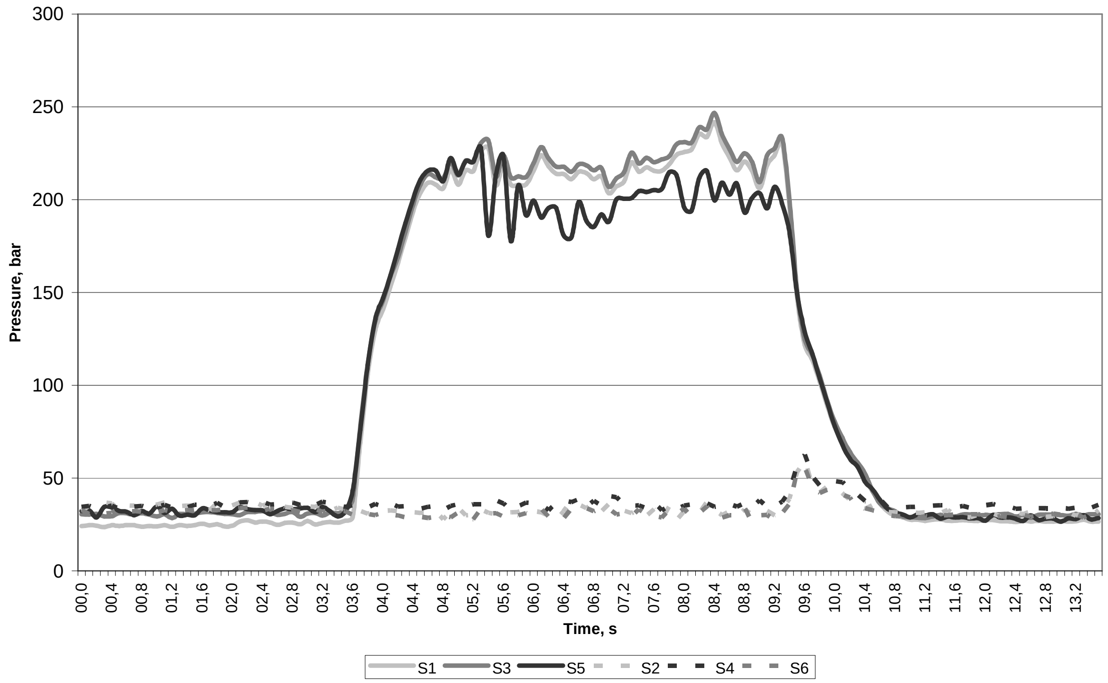

Fig.10. Timing changes in pressure in in-lines and out-lines of hydraulic motors of the robot right arm during a rotation turn on the asphalt road

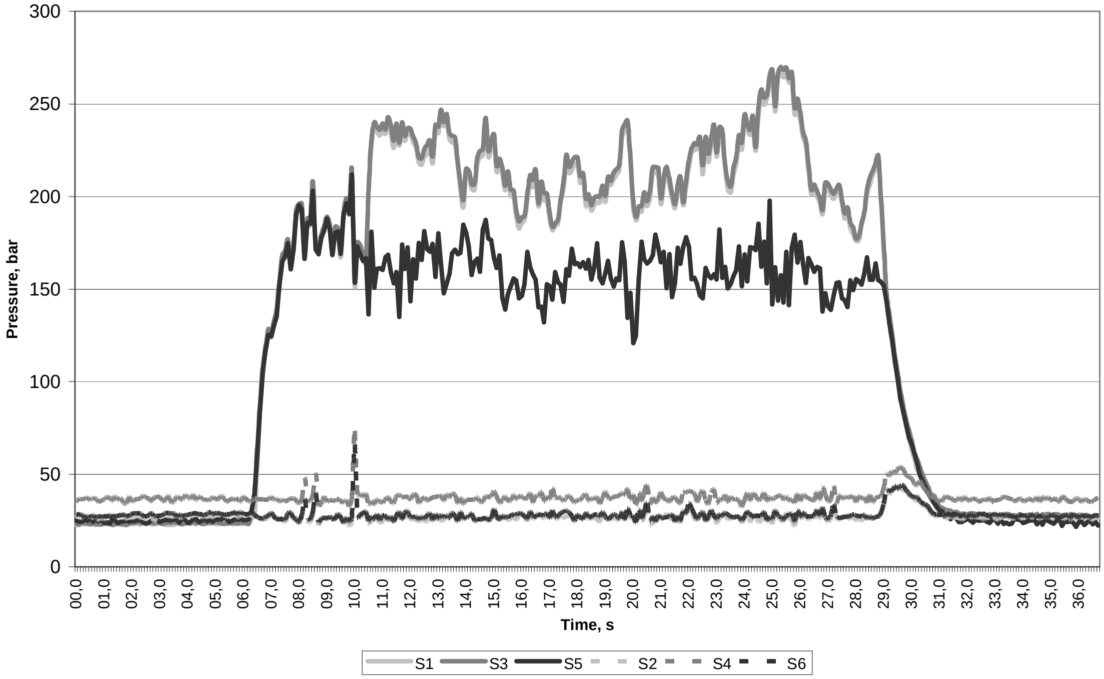

Fig.11. Timing changes in pressure in in-lines and out-lines of hydraulic motors of the robot right arm during a rotation turn on the ground

Fig.12. A pile of ground under the wheels after performing a rotation turn significantly increases the resistance and load og driving system

To investigate the climbing ability of a robot, a test of climbing a slope, with an inclination of 30, 40 and 60%, by a robot was carried out. The surface of the slopes were covered with openwork concrete slabs, lightly covered with grass. The robot climb up all the tested slopes. The biggest load of driving system occurred during a robot was climbing a slope with an inclination of 60%. The timing courses of pressure recorded on in-lines and out–lines of hydraulic motors of the right arm are shown in figure 13. There were significant differences in the pressures on supplying lines between the wheels of the rear axle and the center (S1, S3) and front (S5) up to 200 bar.

The reason for this discrepancy is the different pressures of each axis to the ground. The center of gravity of the robot, in order to increase capacity, is located on the middle axis, which when climbing the slope causes less pressure of the front axle, resulting in a lower load on the front wheel hydraulic motors. The maximum pressure, while climbing a slope with an inclination of 60%, in the central and rear wheels motors was approximately 320 bar and was equal to the nominal pressure of hydrostatic drive system .

While crossing the ditch (figure 14) and shaft (figure 15) there were not so high pressures. While overcoming the ditch of the depth at 0.5 m and slope inclination of 50% the pressure does not exceed 180 bar. Values were slightly smaller on the front wheel due to the lower pressure to the terrain. A good cooperation of wheels was noticed. Slightly less motors cooperate in overcoming the natural shaft - not very good work of front wheel suspension can be seen that results in reduction of pressure to the ground. In effect, the load of the central and rear motors raises.

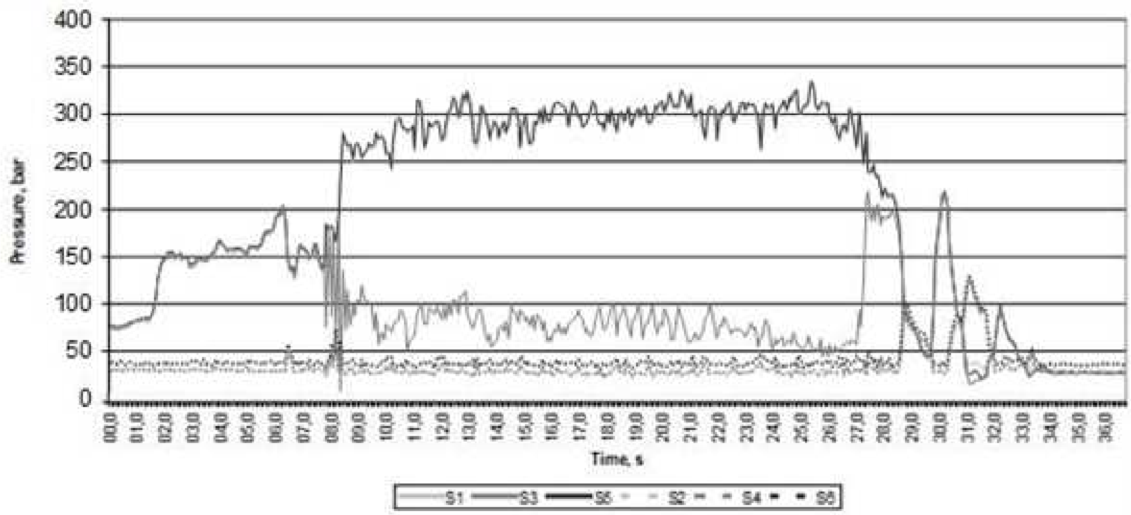

Figure 13 - Timing changes in pressure in in-lines and out-lines of hydraulic motors of the robot right arm while the climbing a slope with inclination at 60%

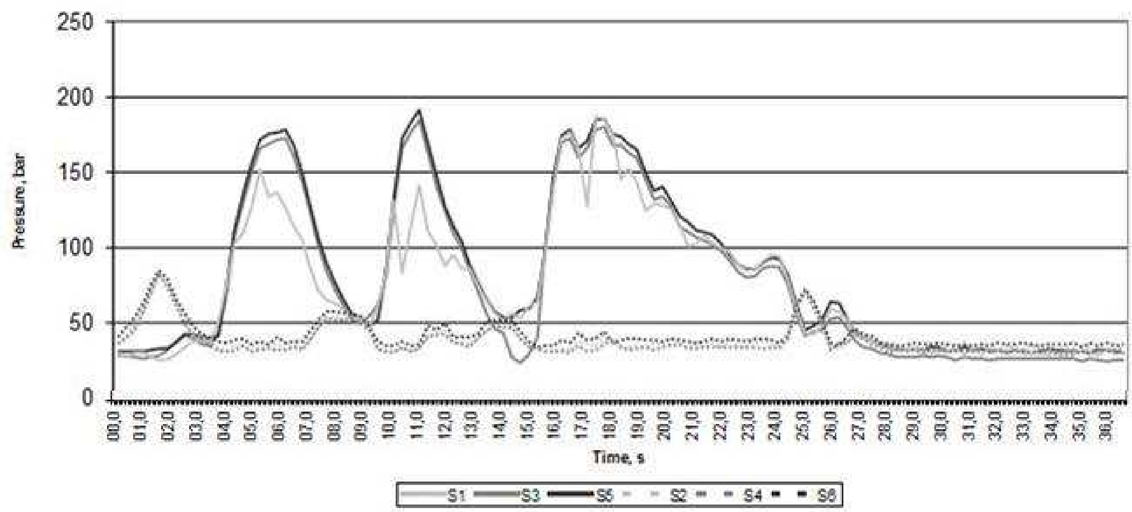

Figure 14 - Timing changes in pressure in in-lines and out-lines of hydraulic motors of the robot right arm while overcoming the ditch

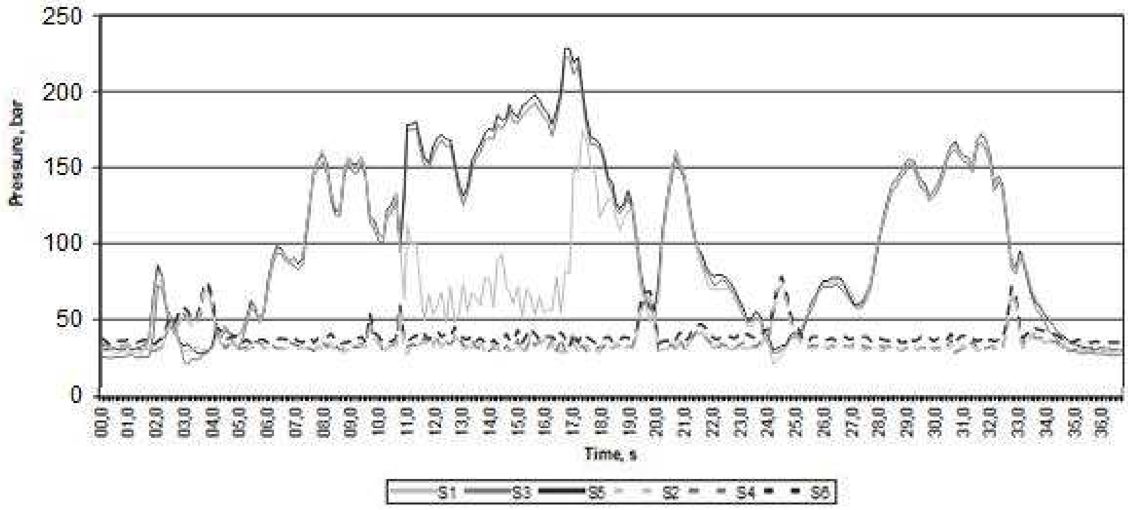

Figure 15 - Timing changes in pressure in in-lines and out-lines of hydraulic motors of the robot right arm while overcoming the shaft

CONCLUSIONS

The measurements allowed to understand better the phenomena and loads of the driving system of the vehicle with 6 x 6 system during maneuvering and overcoming obstacles. Their record in the mechanical driving system is extremely difficult, they have their special cognitive value. They showed that, in accordance to the design principles, the greatest loads occur while rotation in place - it is necessary to bring the wheels to a full slip, and then climb a steep slope - there is a significant load on the rear wheels that requires more tractive forces.

Pressure course, which were recorded in the drive system, indicated that the leakage of flow dividers and gerotor motors which drive the wheels, lower kinematic stiffness of driving system while moving on ground surface – it has no significant effect on the behavior of the robot and load of the drive system and engine. Observed pressure pulsations are caused mainly due to acceleration and braking processes and changes in the robot substrate grip.

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