19h International Research/Expert Conference
”Trends in the Development of Machinery and Associated Technology”
TMT 2015, Barcelona, Spain 22-23 July 2015

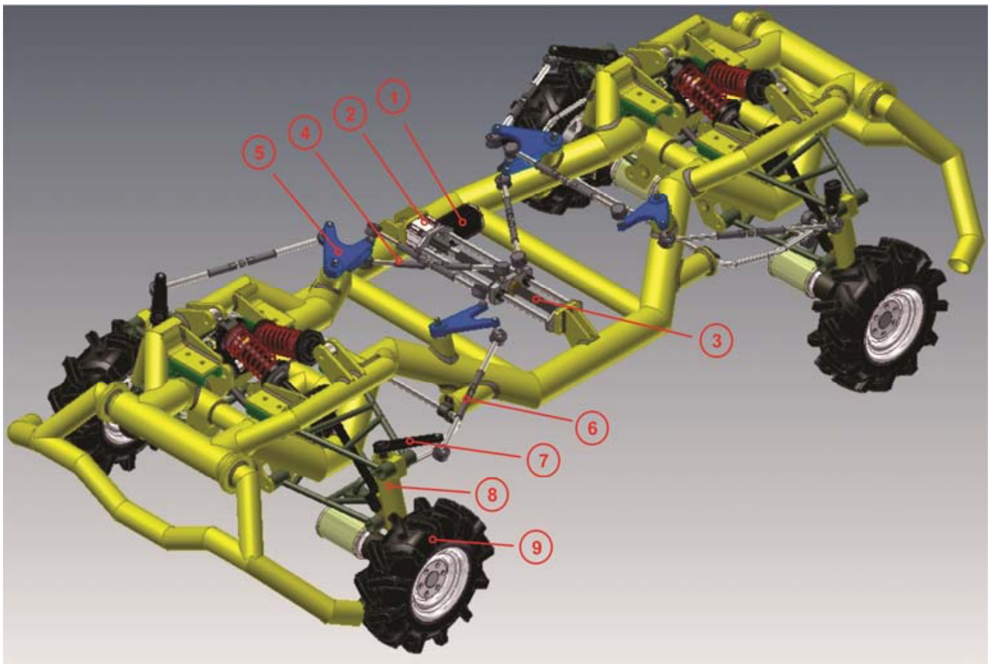
DESIGN OF A MOBILE PLATFORM OF THE ROBOT "MNE-ROBECO''

Darko Skupnjak, MSc
DAIDO METAL KOTOR AD
Industrijska zona bb
85330 Kotor
Montenegro

ABSTRACT
A robot terrain vehicle with combined control - autonomous and remote is being developed at the University of Montenegro. An original design of a mobile platform enabling a robot moving off the roads has been created for the mobile robot "MNE-ROBECO". The mobile platform has got four drive wheels. The Work describes the mobile platform structure, control mechanism, system of mobile platform leaning, mechanism for control and elastic wheel support, including characteristics of the mobile platform related to possibility of moving across uneven terrain.
Keywords: mobile platform, mobile robot, control mechanism, drive wheels

1. INTRODUCTION
A robot „MNE-ROBECO“ [1, 2, 3] is being developed at the Faculty for Mechanical Engineering of University of Montenegro. Having calculated kinematics of a mobile platform, control mechanism was modified and kinematics re-calculated. Based on these calculations a new concept of control mechanism has been adopted as a better one. Picture 1 shows the mobile platform with the new control mechanism for turning the wheels and changing direction of the platform turning.

2. CONTROL MECHANISM OF A MOBILE PLATFORM
For a mobile platform of the robot „MNE-ROBECO“ ,a spacial mechanism has been developed in order to control direction of the mobile platform wheels. This mechanism is shown in Picture 1.
An electromotor with encoder (1) and with a reducer (2) is attached to the control mechanism. From the other side, the control mechanism is connected to the controlled wheels by transferring spacious mechanism. A very important task of this mechanism is to ensure proper kinematics of the wheels turning. Shown construction of the control mechanism enables wheels turning up to $\pm 45^o$ against the vertical plane, having met a basic kinematic criterion of control ie. turning the wheel around the rotation centre.
The output shaft of the reducer (2) is attached to a spiral spindle (3) by a nut and through movable levers (4) makes the fork (5) turns. The fork is placed on the pin with axis inclined for a certain angle against the vertical plane which corresponds to an angle of side inclination of the wheel shaft. This angle is important for autonomy of controlling by directing the wheel and its relative movement against the mobile platform frame.
The fork (5), which is an element of imagined trapezium of control by guiding the wheel, activates the lever (6) and using the lever (7) turns the wheel pin placed in the housing (8).
Transfer spacious mechanism needs to ensure realization of wanted control kinematics with as less as possible mistakes. Such concept of the transfer mechanism is completely conformed with the system of leaning of the controlled wheels (9) in such way that their relative movements against the mobile platform frame do not have any impact to safety and accuracy of controlling.



Picture 1: Mobile platform of the robot „MNE-ROBECO“ with control mechanism

3. LEANING SYSTEM OF THE MOBILE PLATFORM FOR „MNE-ROBECO“

Following literature [4, 5, 6], the leaning system of the mobile platform consists of the mechanisms and elements which transfer in various conditions of motion, all reaction forces and moments generated between the wheels and the terrain to the frame absorbing the striking loads and ensurance of required stability of platform. The leaning system generally consists of four separate systems or mechanisms [4]:

1. Mechanism for guiding the wheel (elements for leading);
2. Elastic support (elastic elements),
3. Elemenst for absorbing oscilation and
4. Stabilizers.

The leaning system of the mobile platform of the robot „MNE-ROBECO“ is based on four drive wheels.

On the mobile platform of the robot, there is a *mechanism for controlling the wheels* consisting of the two oscilating shoulders, upper (4) and lower (5), picture 1. Both shoulders carry the housing (11) with radial and axial bearings where the hub shaft is placed (2).

Elastic elements with the presented mobile platform enables a wheel to lift when bumping to uneven soil (2) and throught the lever (7) pushes and transfers the force generated by the torque for the item A (marked in Picture 2) ie.axis of trigonous carrier (6) which is connected to the platform frame through the pin it turns around (Picture 1). For the same trigonous carrier, the assembly (8) is attached which consists of the pressure torsion spring with elements for connection and adjustment of the spring bias (ie. the platform height, callosity, etc.). Trigonous carrier (6) is turned by lifting the wheel and the assembly spring (8) is compressed, picture 1.

Following marks of the elements in picture 1, projection of force F on the lever (7) multiplied with arm *l1* gives a moment for item A, from one side, while spring multiplied with arm *l2* gives a moment for item A, from the other side. Analysing the forces acting on trigonous carrier (6) from picture 1 we get distribution of forces as shown in picture 2.

For such geometry, under the condition that total moment for the item A of trigonous carrier (6) must be equal to zero we get dependence of the spring force (progressive) and disrupting force F, of course when ignoring the friction forces in the bearing A.

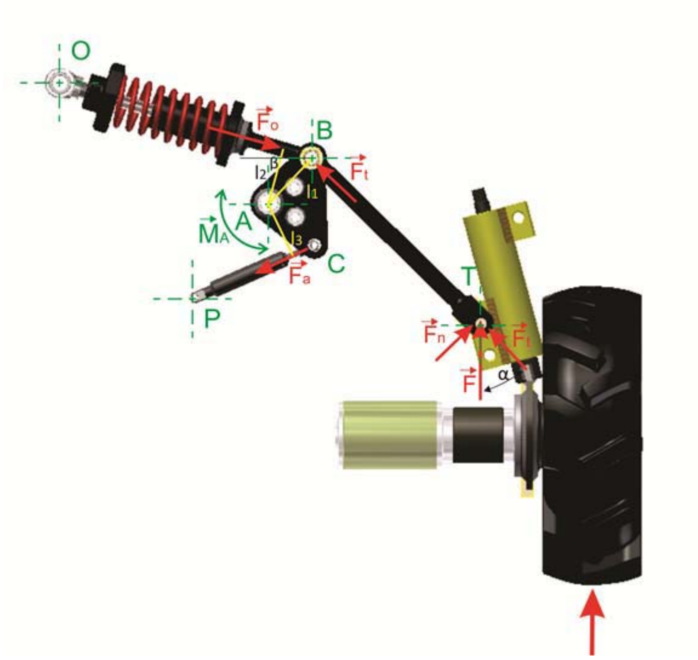
$$\overrightarrow{M_A} = 0 \qquad \text{... (1)}$$

$$\overrightarrow{F_t} \times \overrightarrow{l_1} - \overrightarrow{F_o} \times \overrightarrow{l_2} - \overrightarrow{F_a} \times \overrightarrow{l_3} = 0, \qquad \text{... (2)}$$

ili $F_t \cdot l_1 - F_o \cdot l_2 - F_a \cdot l_3 = 0$ ... *(3)*

Additionally, it should be taken in consideration that the force F_a is of the oscilation absorber (amortizer) in function of the wheel lifting speed. It is also important to point out that this analysis does not include force of stabilizer.

Oscilation absorbing caused by mobile platform moving across uneven terrain is eased by "amortizer" (4 pcs for the platform), ((9) in Picture) which are by one side connected to trigonous carrier (6), and by the other side to the platform frame.



Picture 2: Analysis of forces

The mobile platform for the robot „MNE-ROBECO" has got a *stabilizer* formed as a yoke (10), picture 1, as a whole, and it is connected to the mobile platform frame by the calipers with hard rubber, while it is connected to lower oscilating shoulder by the guides (4). The role of stabilizer is to confront side leaning of the platform when one wheel is lifted up, ie. as the reaction force realigns the platform by lifting up the opposite wheel from the soil and it does not allow its side leaning.

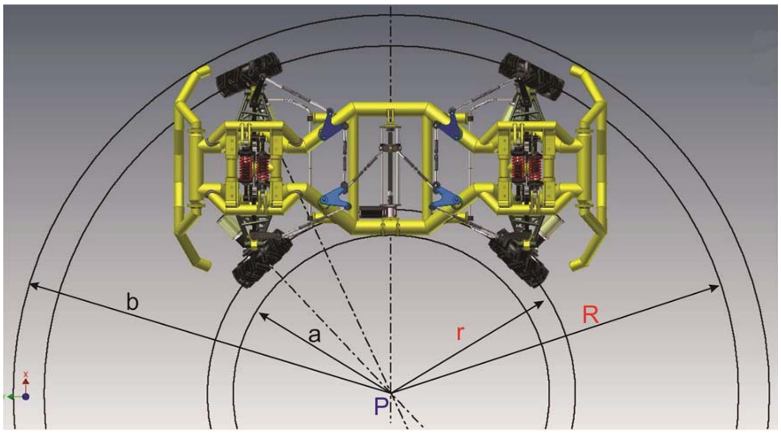
Approach (agressive) and exit angle of the vehicle ie. the mobile platform are the angles shut by the tangent on wheels drawn from the headmost front or rear spot of the vehicle. This characteristic is particularly important for terrain conditions of moving, typical for the mobile platform. Due to symmetry and position of the center of mobile platform mass, approach and exit angles are equal and make 36^{o}. This angle would significantly increase by removing the bumper or changing its construction and it could be increased by 60^{o}.

The angle of the obstacle is an angle made by the angle arms drawn from the lowest point of the mobile platform placed between the wheels, so the same affect the wheels. This angle is 24^{o}.

The side angle of inclination of the terrain across which the vehicle can move without sliding or tumbling down the inclination. This angle depends on the height of the center of gravity, trace of vehicles and coefficient of friction between the wheels and the base. Maximum angle of the side inclination can be defined only for specific conditions of work.

The angle of climbing is the angle of the section inclination of the road which can be overcome by the mobile platform without sliding or tumbling around the rear shaft. This size depends on the position of the platform center of gravity, coefficient of friction between the wheels and the base and generally on number and positions of driving shafts [7]. With the vehicles being highly passable, maximum surmountable angle of inclination is almost usually 100% (45^{o}). „MNE-ROBECO" has got four wheels drive, so experimental testing is expected to give the best possible results.

The lowest height over the stand surface is distance between the lowest immovable spot of the vehicle and horizontal base. This characteristic is more often called the vehicle clearance. In that sense, there is clearance between the wheels of one shaft, intermediate shaft clearance and clearance in front of, between and behind the shafts [7]. Clearance of the vehicle, approach angles and vehicle obstacle have very important function when determining practicability of the terrain vehicles. Turning circle of the vehicle is a circle of diameter 2R (picture 3) described by outer control wheels on horizontal surface when reaching the highest point of turning the wheels, which is approximately ±45° with the mobile platform MNE-ROBECO. The smallest and the biggest circle of the vehicle turning are important for the practice. Diameter of the smallest/the biggest turning circle is encircled by projection of that point of the mobile platform which is the nearest / the farthest to the rotation center at the moment when the control wheels are turned to the highest point.



Picture 3: The smallest (r) and the biggest (R) circle of turning the mobile platform.

4. CONCLUSION

The mobile platform is designed for the mobile robot „MNE-ROBECO", which will be able to move across the terrain of various configurations. Mobile platform operation has been simulated by software PRO/ENGINEER and it has confirmed that the mechanism for controlling turning, i.e. guiding the wheels, including whole mobile platform meet the set requirements. Also, kinematic calculation of control mechanism and calculation of load of elements of lever mechanism which will be subject of the next work has also been calculated.

5. AKNOWLEDGEMENT

The author is a student of Phd studies at the Faculty for Mechanical Engineering at University of Montenegro. The work is part of doctoral thesis and project of multi-functional service robot „MNE_ROBECO", financed by the Ministry of Science of Montenegro.

6. REFERENCES

[1] Skupnjak D., Mijanović Markuš M., Mijanović Z., Vukasojević R.: Design of Remote Computer Controlled four-Wheeled Mobile Platform, 17th International Research/Expert Conference "Trends in the Development of Machinery and Associated Technology" TMT 2013, Istanbul, Turkey.
[2] D. Skupnjak: New Design of Off-Road Mobile Platform for Service Robot, Virtual Journal MACHENES, TECHNOLOGIES, MATERIALS. ISSN 1313-0226. ISSUE 4/2013, pp. 37-40.
[3] Vukasojević R., Mijanović Markuš M., Skupnjak D., Mijanović Z.: Mobile Platform for the Terrain Robot „Robeco", MACHENES, TECHNOLOGIES, MATERIALS. ISSN 1313-0226. ISSUE 4/2013.
[4] http://meskrusevac.inforbiro.com/saobracaj/images/download/Oslanjanje.pdf
[5] Nikola Vujić: Control and transfer mechanism of the Control system: http://nikolavujic.weebly.com/uploads/3/4/8/0/3480733/upravljacki_mehanizmi.pdf
[6] Lectures: Vehicle control and control mechanism: http://ttl.masfak.ni.ac.rs/TKV/VIII_UPRAVLJANJE_VOZILOM_I_UPRAVLJACKI_MEHANIZAM.pdf
[7] Aleksandar Stefanovic: ROAD VEHICLES – design essentials - NIŠ, 2010., Publisher: Center for motors and motor vehicles at the Faculty for Mechanical Engineering – Nis and Center for safety at the Faculty for Mechanical Engineering in Kragujevac, ISBN 978-86-6055-005-9.