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Construction of a Special Mobile Robot that Uses a Special Travelling Wheel

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Abstract. This paper deals with the engineering design of a solution of a mobile robot that uses a special travelling wheel for transmission of motive power onto a surface. It further explains the principle of a vehicle travelling wheel that – according to an actual situation of the surface – changes the way of the wheel movement on the surface. The work content in our workplace is the engineering design of the solution of a mobile robot frame which uses a special travelling wheel pursuant to our patent to transfer the driving force onto the surface. This travelling wheel is able to transform and adapt to the driving conditions. Since it is an unmanned ground robot, not so common technical solutions can be used. Because it is also meant to be used in a rough terrain, the concept of four-wheel drive has been chosen and a four-wheel chassis has been designed to make it more simple. In terms of need of excellent handling and movement fluency, all four wheels will be directionally steered (4WS) and will be placed as much in the frame corners as possible in order to have a space for 90° steer angle.

1 Introduction

Most of the common vehicles are meant to move on a road or in a gentle terrain. "Allroad" types of vehicles make it possible to drive to a certain degree of a terrain difficulty. This difficulty is specified not only by the terrain irregularity but also by the terrain surface that needs to have the wheel-centres increasing the traction capability for instance in mud, on snow etc. The most important vehicle parameter influencing the movement in the terrain is its dimension. The primary dimensions include length, width and height. These determine the position of centre of gravity and influence the vehicle stability, hence the slope accessibility. Commercial vehicle dimensions are limited by law. However, special purpose off-road machines are granted.

Based on findings, it is possible to justify the following devices for off-road vehicles. Four-wheel drive with full differential concord is often used, which increases the surface contact of driving-wheels and improves the adhesion and overall mesh characteristics. For the same reason, larger wheels with bigger surface contact are used in the terrain. Tyres with lower tread pattern density (approximately 30%) and bigger height are used. It increases bogging of tread pattern into the ground and also the adhesion, and at the same time the tyres have better self-cleaning properties – when the tyre-tread pattern is clogged, the adhesion gets rapidly worse. The tyre construction is usually resistant to mechanical damage and allows lower tyre pressure. On one hand it increases the internal resistance, but on the other hand it increases the tread contact area. The wheel suspension is usually with bigger travel and swing, which is provided by solid axles. The solid axles efficiently ensure continual connection of all wheels with the surface. In terms of vehicle drive, a wide range of changing gears is used for optimal use of drive potential under all conditions. Additional speed reducer for very low speed and acceleration secures low deviations and shock by influence of unevenness and at the same time they increase the resultant torque.

This paper is focused on problems of movements of means of transport in the terrain, especially those that have the ability of efficient motion not only in the terrain but also on a reinforced road with a grade level. In most of the cases of the existing solutions, there are bigger or smaller compromises between these two movements.

It is possible to improve the terrain passability by a special construction of wheels or chassis using a wheel-track chassis. We talk about a wheel chassis on which tracks are attached. It uses advantages of both chassis. Another option is to use a walking mechanism – currently it is used by unmanned mobile robots. It is a technology of machine movement using so-called "legs"; with their help the robot overcomes differently broken terrain. In case of autonomous robots, the terrain is being scanned and analysed in the current time, and an ideal movement is being chosen for its overcoming. The disadvantage is complexity of the whole system.

Currently, track adapters are an often used way of improving the terrain passability of the means of transport. It is used mostly for moving on snow, but it is possible to use it all the year round. So it uses both advantages and disadvantages of track chassis which are

separately divided for each wheel. The assembly does not interfere in the vehicle construction. Another relatively new accessory is so-called "J-wheelz" which is assembled on a wheel disk. Its advantage of increasing the surface contact in soft ground and on snow is used. The system is very simple; however, there is a disadvantage of unbalance that results in force stress of chassis parts during higher speeds.

The current trend is a segregation of people and the means of transport, such as the unmanned aerial vehicles or the mobile robots. The reason is the human health protection and a smaller size with keeping or improving the function. That is why this paper deals with the telecontrolled robot (or a teleoperator).

Figure 1. Illustrations of special constructions for improving the terrain passability: wheel-track used in forestry [1], possibility of using track adapters and so-called "J-wheelz" on an off-road quadbike.

2 Description of a mobile robot which is being prepared at TUL

Relatively new categories of the means of transport are unmanned ground vehicles (UGV). In most of the cases these are telecontrolled means of transport with a specific determination such as transport or manipulation with dangerous objects, movement in the inaccessible terrain etc. where it is not possible to use big or man-controlled vehicles. Not only precise and sophisticated spacecraft but also telecontrolled municipal mowers for steep terrain are included in this category. It is necessary to provide maximal reliability and effectiveness when moving among moulded and natural obstacles. Therefore the vehicles are often equipped with technical solutions which are not usually used with utility and personal vehicles.

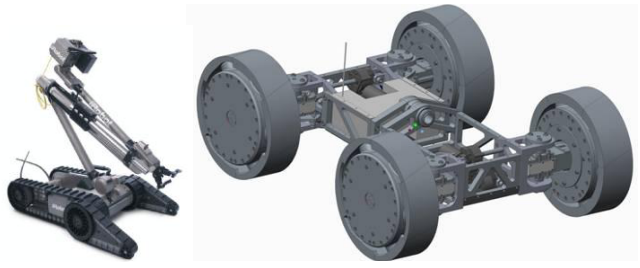

Figure 2. Illustration of an unmanned mobile robot [2] and the engineering design of a robot with special travelling wheels by TUL [3].

The work content in our workplace is the engineering design of the solution of a mobile robot frame [3] which uses a special travelling wheel [4] pursuant to our patent [5] to transfer the driving force onto the surface. This travelling wheel is able to transform and adapt to the driving conditions. Since it is an unmanned ground robot, not so common technical solutions can be used. Because it is also meant to be used in a rough terrain, the concept of four-wheel drive has been chosen and a four-wheel chassis has been designed to make it more simple. In terms of need of excellent handling and movement fluency, all four wheels will be directionally steered (4WS) and will be placed as much in the frame corners as possible in order to have a space for 90° steer angle. Therefore independent steering by a servomotor for each wheel has been chosen. The robot will further have the possibility of concordant and disconcordant steering.

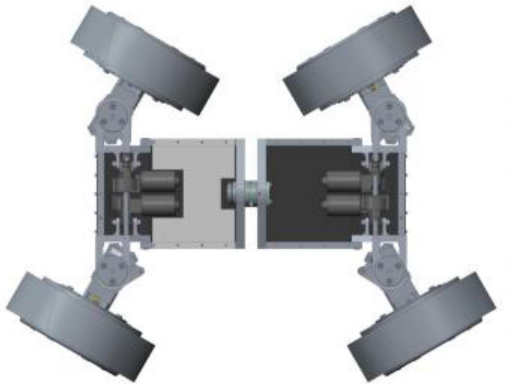

Figure 3. Demonstration of directional control the robot (4WS) [3].

As high power and torque is expected for the chosen dimension (when considering the size and possibilities of such electric motors), each wheel will have its own and independent driving gear. This array is also advantageous in order to comply with the Ackermann steering condition and the condition of different wheel speed in the curve. Everything will be controlled by Electronic driving control system, which will control the wheel angle and speed of each wheel separately. There will not be the problem with mechanical differential anymore. It is suitable to use a solid axle for slow off-road vehicles. Therefore the frame will be divided into two mutually unsprung parts that will be connected by a longitudinal swing pivot.

3 Construction of the used, special travelling wheel

The aim of this invention is achieved by using a travelling wheel for driving on the road and/or in the terrain whose principle is that the siding segments in the travelling wheel body are sorted adjustable between the position for driving on the road and the terrain position in which the individual siding segments are diverted from the circumferential direction of the caster. Among the siding segments there are gaps in the direction of the circumference of the travelling wheel and these gaps interrupt the rolling surface of the travelling wheel. When setting the siding segments into the circumferential

direction, the travelling wheel goes on like a usual travelling wheel, which is an advantage when using on the surface of common roads. After turning the siding segments into sloping positions (when considering the circumference of the travelling wheel), there will be circumferential gaps, thereby improving the passability in the rough and/or fragmented terrain. The angular displacement of the segments can be set according to concrete driving conditions. In the version where the axis of the pivot is skew (considering the rotation axis of the travelling wheel) the wheel track can be enlarged by turning the siding segments. It increases the vehicle stability in the rough and/or sloping terrain.

Two engineering designs of the special travelling wheel have been prepared. The first one uses the variant with the bevel gear (advantages: lower number of parts, rigidity; disadvantages: because of the offset it is necessary to use hypoid gears (complexity, price), it is necessary to add a self-locking gearbox, unsuitable gear ratio).

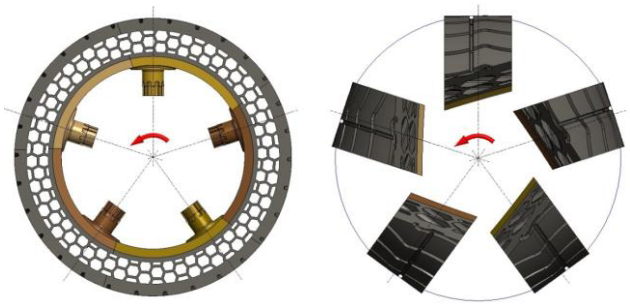

Figure 4. The principle of "walking" wheel – closed segment (rolling motion) on the left, turned segments (walking motion) on the right [4].

The other design uses the slotted link mechanism (advantages: self-locking, suitable gear ratio; disadvantages: bigger number of parts, more complex construction). The construction is solved as a prototype (not intended for mass production)

Due to the reasons mentioned above, the variant has been chosen, where the segment steering functions on the principles of the slotted link mechanism. A handle is attached to the rim segment (more precisely to the pivot around which the segment is shifting). On the other end of the handle is pivoted a stone which is shifted-placed in the slot. When moving the slot in the direction which is vertical to the direction of the advance motion of the stone in the slot, we achieve the rotation of the rim segment. When using this mechanism, the segments are placed all over the travelling wheel circumference and rotation of all the segments by the same angle is controlled by a linear shift of a subframe with slots. The shift of the subframe is ensured by using a motion screw to which a drive is attached. The principle of a slotted link mechanism and a motion screw used for the travelling wheel construction is clear in the Fig. 5.

The next important issue is the tyre construction of the walking wheel with divided tread segments. The construction of the tyre used has not been thought of in detail yet, only one of the possible principles is introduced here. We talk about self-sealing tyres that are used for instance for military purposes. The space between the rim and the tyre tread is filled with honeycomb replacing the compressed gas.

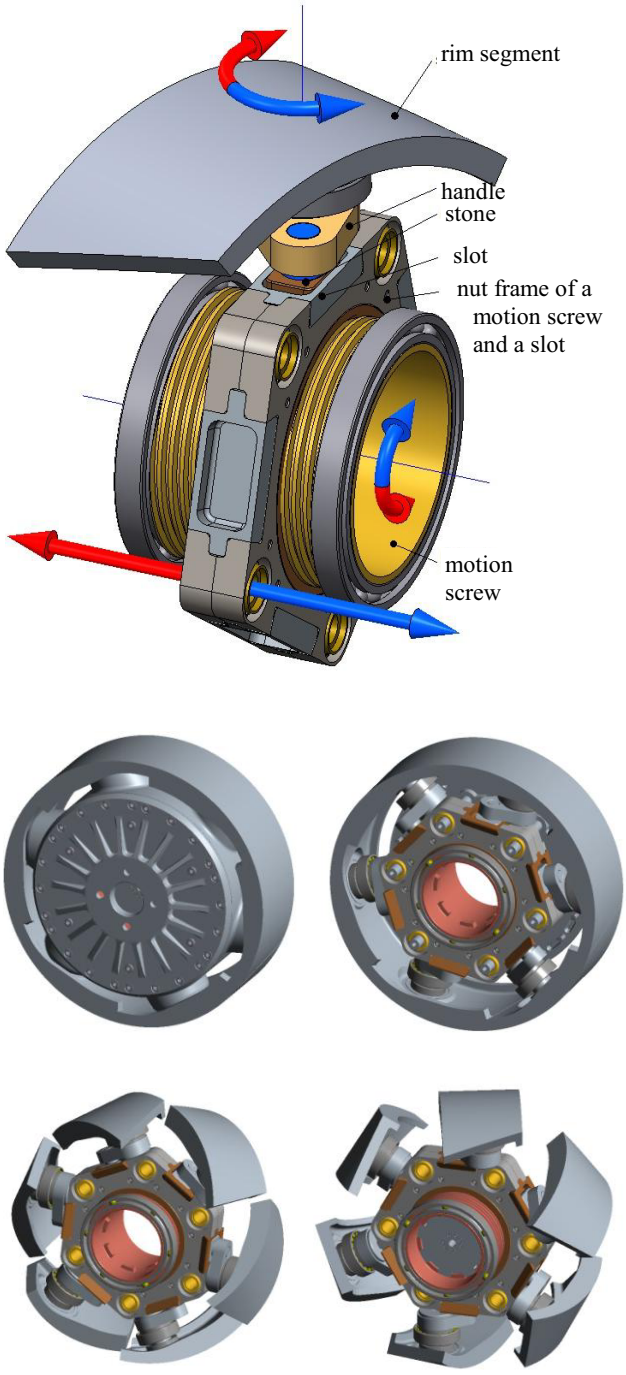

Figure 5. The principle of turning segment using slotted link mechanism and motion screw; view of travelling wheel with closed and turning segments [4].

In the Fig. 7 a design of a construction of a special travelling wheel placing into a solid axle is illustrated. It means that the motor is placed into an aluminium alloy made box, divided symmetrically. The front part of the motor is closed by the box cover which is simultaneously used as a "housing" for the front rotor bearing. An electric motor and a gearbox from an accumulator drill were used for the caster drive. Part of the box is also

space for placing the motor control unit electronics. This space in the second front-part of the box is closed by the electronics cover. There is also a cooling fan in the electronics cover. In the normal mode, cooling air for the rotor is sucked in through the idle mode fan. Sheet metal covers of cooling are used for bringing air to the motor entry in the box cover. Housings of axial tapered roller bearings are also a part of the motor configuration. These housings are – together with two parts of the box – connected by appropriate screw-connection and with the whole box it creates steering pivot of the wheel-direction controlling.

Figure 6. Illustration of a self-sealing tyre [6].

4 Summary

At the present time, the construction lay-out of the robot is processed and complete design drawings are being done for production of a functional sample of the mobile robot that will use a special travelling wheel for its motion for driving on the road and/or in the terrain whose principle is that the siding segments in the travelling wheel body are sorted adjustable between the position for driving on the road and the terrain position in which the individual siding segments are diverted from the circumferential direction of the caster.

It is suitable to use a solid axle for slow off-road vehicles. Therefore the frame will be divided into two mutually unsprung parts that will be connected by a longitudinal swing pivot. In the frame structure are used bolted panels of aluminum alloy which are maximally lightened. The width of the frame is designed with regard to the installation of electronics and batteries. For covers parts of the robot are selected from composite material. Directional control of individual wheels is chosen concept 4WS (four-wheel-steering).

When the robot is manufactured, its driving characteristics will be verified.

Acknowledgements

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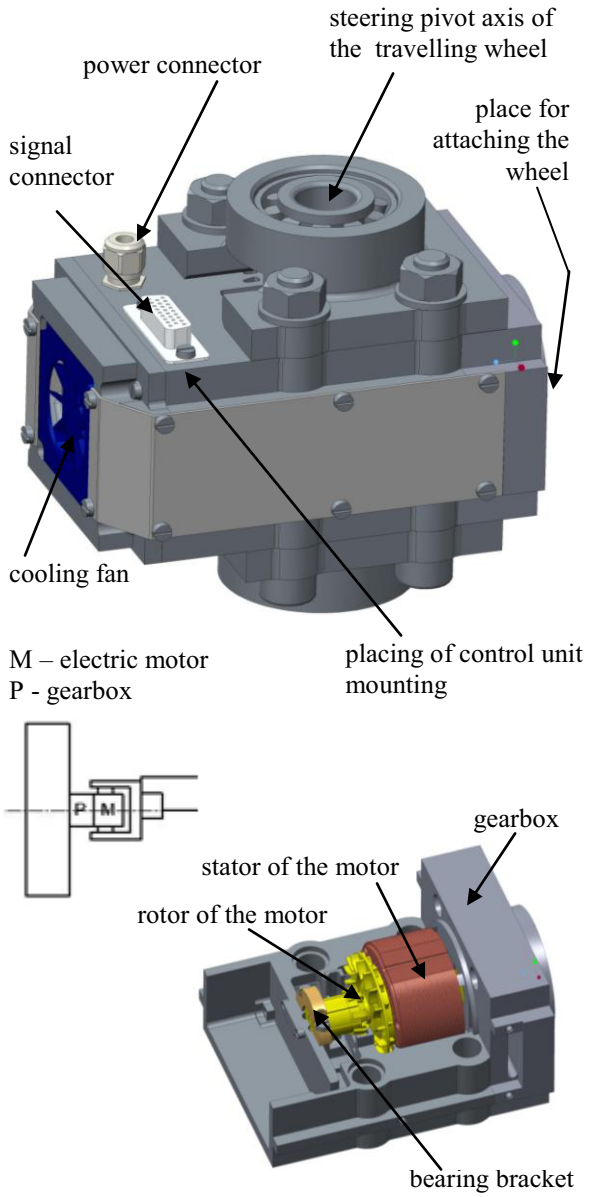

Figure 7. Configuration of a steering pivot with a bow with propulsion [3].

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