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Wheeled robot for rough terrain

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Abstract: The article deals with the design of a robot chassis intended for movement on uneven terrain. The chassis is composed of a front part with two parallel arranged wheels and two tiltable parts with serially placed wheels. This concept adapts to uneven ground surfaces.

1 Introduction

Wheeled chassis intended for movement in rugged terrain have rigid suspension chassis that only partially compensate for surface irregularities. The use of such types of chassis is often excluded, as they are able to overcome obstacles only up to one third of the wheel diameter. In order to overcome dimensionally larger obstacles, unnecessarily large wheels must be used, which unnecessarily increases the dimensions of the chassis and makes it impossible to apply the chassis in confined spaces. The use of unnecessarily large and heavy chassis also means increased energy requirements for the operation of such a chassis.

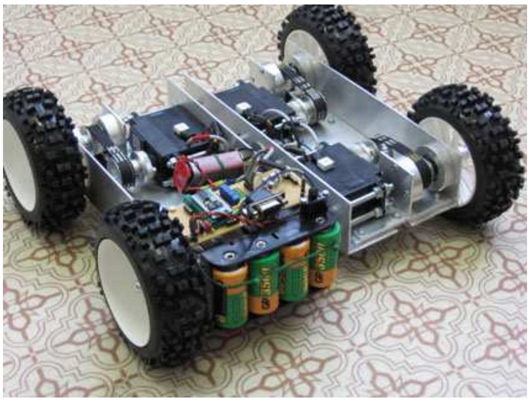

Figure 1 Wheeled robot with a longitudinally divided chassis

Previously designed mobile robots adapt well to uneven terrain, but in some cases the obstacle clearance is insufficient and the robots cannot develop sufficient traction to overcome uneven terrain (Figure 1, Figure 2).

The design of a wheeled robot with a longitudinally divided chassis (Figure 1) seems to be a good solution, but experiments have shown that this chassis concept is unsuitable for obstacles larger than the radius of the robot's wheel.

The robot with adjustable chassis height (Figure 2) already offers better characteristics when driving uneven terrain, but its stability when moving is worse, and the traction of this chassis is also insufficient for overcoming obstacles larger than the wheel radius.

A new suitable solution would be to design a chassis with six wheels with multiple joints for better adaptation to uneven terrain.

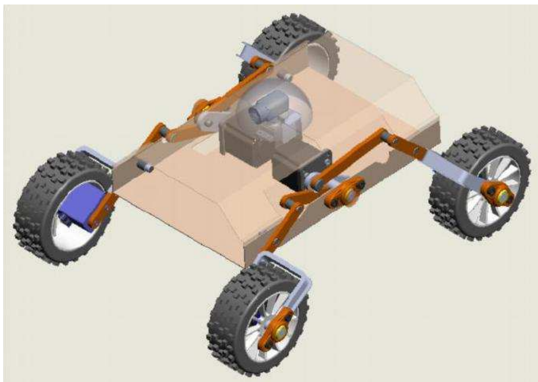

Figure 2 A robot with an adjustable chassis height

2 Control system design

This wheeled robot (Figure 3) is intended for movement on rugged terrain, while the designed arrangement allows overcoming obstacles with a height corresponding to the size of the chassis wheel diameter. With a regular four-wheel chassis, this height is only about a third to half the size of the wheel diameter.

This proposed robot concept (Figure 3) uses six driven wheels for its movement with separate motors for each wheel. Two pairs of wheels on both sides of the chassis are placed on the left and right swing arm, so that the wheels follow the terrain as best as possible during the movement of the chassis. This ensures that the wheels are in contact with the ground even on uneven terrain, thus ensuring maximum traction and the ability to overcome obstacles.

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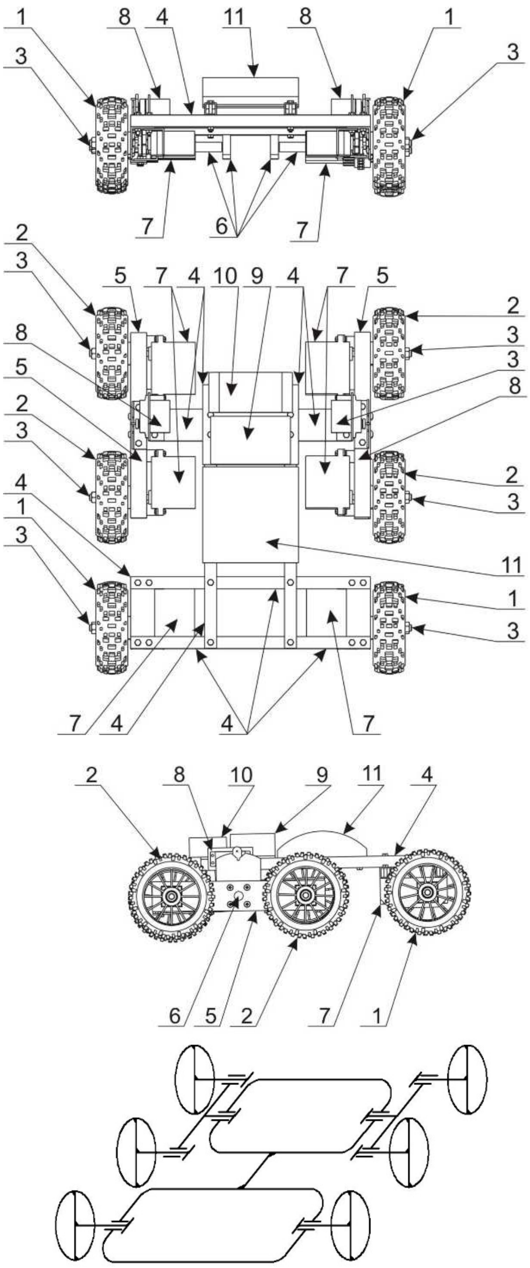

1 – Wheel stored in the frame; 2 – Wheel stored in swinging arm; 3 – Shaft with bearing and bearing housing
4 – Frame; 5 – Swing arm; 6 – Bearing mounting of swing arm; 7 – Engine with gearbox and clutch for wheel drive; 8 – Engine with lever mechanism for chassis reconfiguration; 9 – Module with electronics; 10 – Accumulators; 11 – Handling superstructure

Figure 3 Robot concept for rough terrain

The chassis of this robot (Figure 3) also has the ability to reconfigure from a six-wheeled chassis to a four-wheeled chassis. For this reconfiguration, an engine is placed to realize the reconfiguration of the chassis with a lever gear. Reconfiguration to a four-wheel chassis is more advantageous when moving on terrain without obstacles, and thus it is possible to turn off the motors of unused wheels and thus save energy in the accumulators, which makes it possible to increase the range of the chassis.

The essence of this robot consists in the fact that the chassis contains one pair of wheels on shafts with bearings and bearing housings firmly connected to the chassis frame and two pairs of wheels on the sides of the chassis, whose bearings with bearing housings are fixed on swinging arms.

The advantage of this robot lies in the fact that this arrangement makes the chassis adaptable to uneven terrain and thus achieves a better contact of the wheels with the terrain, which ensures better traction of the chassis and drivability of the terrain.

In addition, this chassis can be reconfigured if necessary, i.e. changed from a six-wheeled to a four-wheeled one.

The designed robot (Figure 3) contains six wheels (1), (2) and a frame (4) with swinging arms (5). In the front part, the frame (4) has wheels (1) on both sides attached to the shafts and stored in bearings with bearing housings (3). In the rear part of the frame (4), in the bearing housings (6), swinging arms (5) are placed on both sides, on which are placed two wheels (2) fixed on the shafts in bearings and bearing housings (3). The rotation of all wheels is ensured by a separate motor with a gearbox and clutch (7) for each wheel (1), (2) separately. Swinging arms (5) with wheels (2) rotate freely in the bearing housing (6) according to terrain irregularities. The swinging arms (5) can also be tilted using a motor with a lever mechanism for reconfiguration (8). By tilting the swinging arms (5), it is possible to reconfigure the chassis from a six-wheeled to a four-wheeled one, in which it can move on flat terrain without obstacles in a more energy-efficient mode. In the case of uneven terrain, it is possible to reconfigure the chassis to a six-wheeled one using the engine with a lever mechanism (8), which better copies the uneven terrain and thus achieves better traction. The module with electronics (9), accumulators (10) and handling superstructure (11) are located in the upper part of the frame (4).

3 Simulation of crossing an obstacle the size of a wheel

With a suitable distribution of weight on all wheels, a chassis with this concept should be able to overcome obstacles with a height corresponding to the size of the wheel diameter, such as a curb. With a regular four-wheel chassis, this height is only about a third to half the size of the wheel diameter.

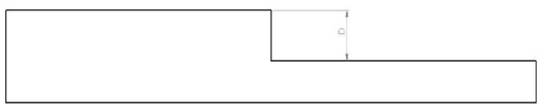

Figure 4 The shape and size of the obstacle

For these purposes, a simple chassis model with such a concept was built in the simulation program based on the kinematic diagram and simulated when passing such an obstacle.

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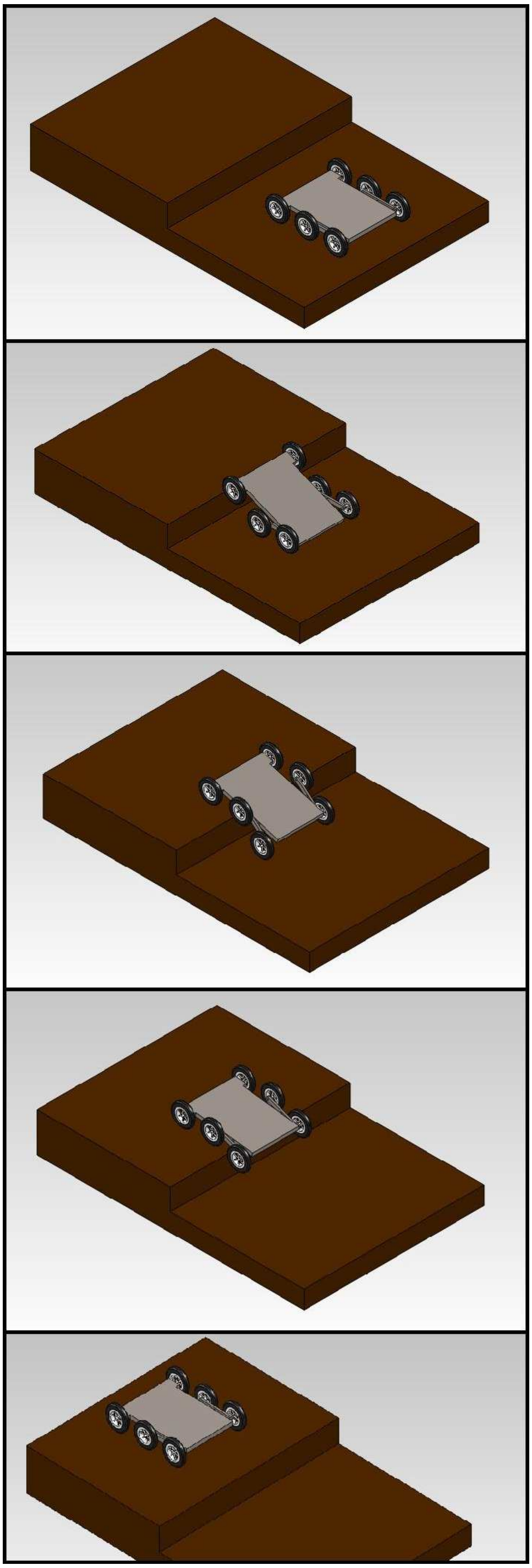

Figure 5 Phases of the robot crossing an obstacle

The chassis of the robot overcomes the obstacle in such a way that each axle overcomes it individually.

4 Design of robot chassis drives

An approximate calculation (1) was used for the design of the robot chassis drives:

$$F_{app} = m \cdot g \cdot (\mu \cdot \cos\alpha + \sin\alpha + \frac{a}{g} \cdot \vartheta) \qquad (1)$$

Where:
- *m* is the weight of the robot, we assume a total weight of 6kg with a load capacity of 2kg
- *g* - gravitational constant
- μ - traction coefficient of friction
- α - the maximum slope of the terrain, considered is 30°
- *a* - chassis acceleration
- *R* - wheel radius, resulting from the selected wheels
- υ - coefficient of rotational resistance
- J_c - total moment of inertia of all parts needed for later calculation
- k_b - safety coefficient

It is possible to determine the approximate movement speed of the robot for the selected drive (2):

$$v = \left(1 - \frac{M1}{M}\right) \cdot n \cdot \pi \cdot 2 \cdot R \qquad (2)$$

5 Chassis reconfiguration mechanism

When moving the chassis, it may be advantageous to raise the wheels of the middle axle so that they do not contact the ground. This is how we get a four-wheel chassis with a rigid frame. We can prevent free rotation of the arms, slightly raise the action superstructure, turn off the motors of these wheels and thus save energy.

When designing the mechanism, an effort was made to minimize the consumption of the motor used for reconfiguration when the axle is raised. There was also an effort to ensure that the arm could tilt freely as it is in the original concept of the chassis, and only in the case of lift, this rotation was blocked (Figure 6).

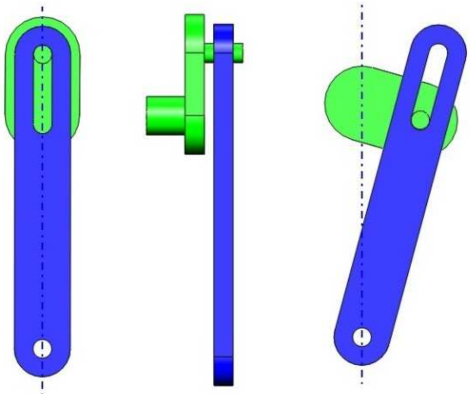

Figure 6 Reconfiguration lever mechanism

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The mechanism is based on two levers. One of them (green) is driven by a motor. This lever has two positions. Turning it also turns the second lever (blue). In this second position, when the moment is applied to the second lever, the force of the drive motor is not needed, since the force transmitted to the first lever passes through the axis of its rotation and thus acts only as a radial force (Figure 7, Figure 8).

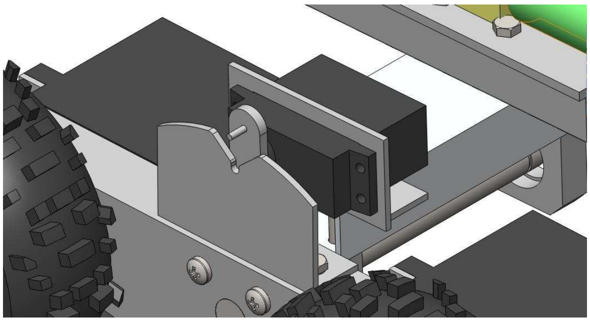

Figure 7 Construction of the reconfiguration mechanism

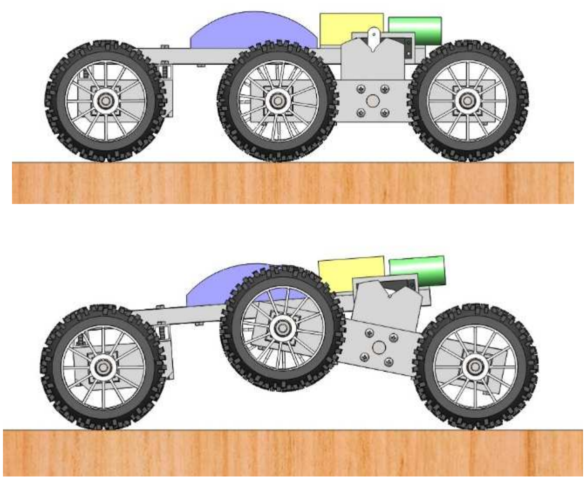

Figure 8 Reconfiguration of the robot chassis

The designed wheel bearing shaft was dimensioned and checked using the Finite Element Method. Stresses are reduced according to the Mises theory of strength (Figure 9, Figure 10).

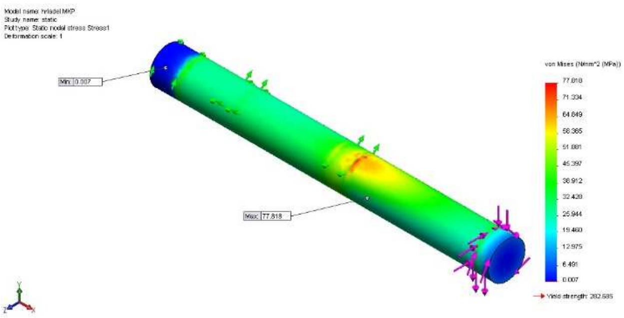

Figure 9 Calculated stresses on the shaft

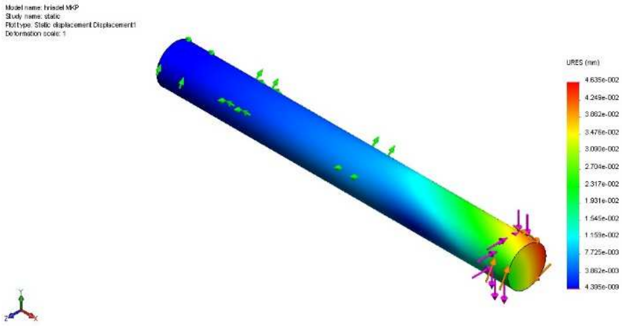

Figure 10 Calculated deformations on the shaft

The frame (Figure 11) is composed of aluminium alloy profiles. The wheel shafts as well as the swing arm shaft are made of steel. The material of the bearing houses is an aluminium alloy. The wheels are fixed on the shaft with a nut. The control of stresses and deformations is in Figure 12.

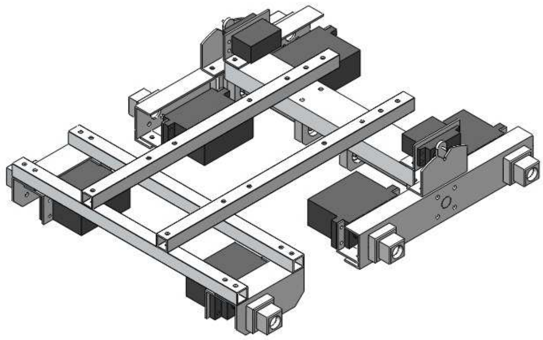

Figure 11 The designed chassis frame of the robot

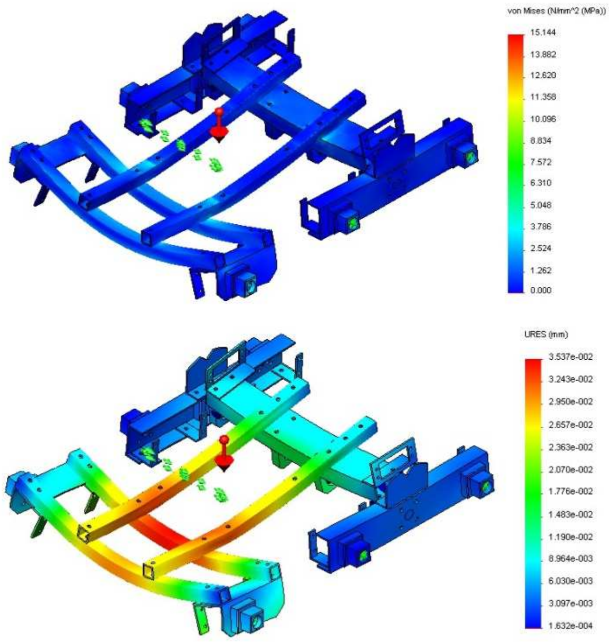

Figure 12 Stresses and deformations of the robot chassis frame

The designed swinging arm was loaded with the estimated force during the simulations and the stresses and strains were determined (Figure 13).

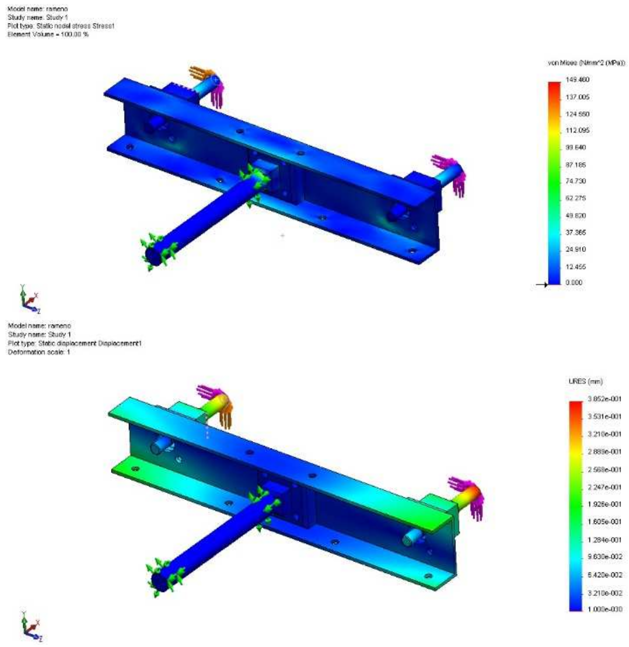

Figure 12 Stresses and deformations of the swinging arm

The realized prototype of the mobile robot was experimentally verified both indoors and outdoors on obstacles exceeding the size of the wheel, and the robot overcame all test obstacles.

Figure 13 Mobile robot prototype

6 Conclusion

The article discussed the design of a mobile robotic chassis that better overcomes locomotion over uneven terrain and is able to overcome obstacles even higher than the size of the wheels, even without increasing the height of the robot chassis and increasing the height of the center of gravity. The proposed solution is even redundant and reconfigurable because it contains an additional degree of freedom in the chassis for modification of the chassis or improvement of maneuverability when overcoming obstacles.

A similar approach to improving the properties of products can also be applied in other areas where innovation and the addition of new functions to existing products is needed.

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