ROLV – A Hybrid Wheel Robot Using Compliant Mechanisms for Locomotion

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Abstract: This work describes the design of a hexapod robot with hybrid wheels. The integration of compliant mechanisms in a mobile robot was a main focus during the design process. Compliant mechanisms are integrated in the trunk and in the coupling between the trunk and the drives for damping, and thus for reduction of internal mechanical stress. Three types of effectors are available: A wheel, a stiff hybrid wheel and an elastic hybrid wheel. The elastic effectors are designed for using resonance effects for locomotion.

Keywords: legged wheel; robot locomotion, climbing

1. INTRODUCTION

Agile locomotion in various terrains is still a challenge relative to the mechanical design of robots. On flat terrain, wheeled locomotion is still the best choice under the focus of ground impact forces, velocity and power effort. For the locomotion in difficult terrains like stairs, scree or even natural ground special legged systems (walking robots) have been developed with often a complex mechatronic design. Additionally there are some biologically inspired robots [1] using hybrid wheels for locomotion e.g. the WHEGS® robots [2], RHex robots [3] and ASGUARD ROBOT [4]. The effectors of these robots are mostly constructed in a very stiff way; they are not designed for using resonance effects for locomotion.

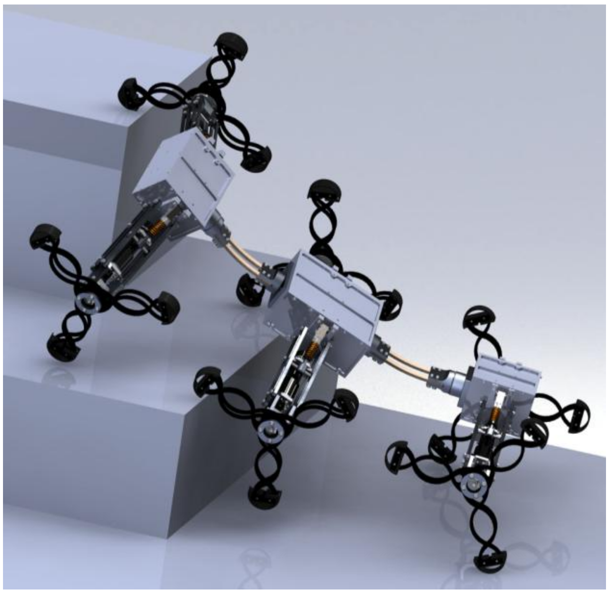

Fig. 1 RoLV robot is designed for the locomotion on different terrain. The robot is parted into three subsystems connected by compliant joints. The 'legs' are designed with a damping behavior

In this paper the design of a hexapod robot called RoLV (**Ro**lling **L**eg **V**ehicle) is introduced. It's an experimental hexapod platform; different effectors can be mounted at the robot in order to compare the different types of locomotion.

2. DESIGN

2.1 Robot platform

The RoLV robot (fig. 1) is designed for agile locomotion on flat and structured terrain. Its mass is about 11.5 kg. The size is about 1 m (length) x 0.6 m (width) x 0.3 m (height). The robot is design as an autark mobile system with onboard energy supply (22.2 V, 3.4 Ah, Lithium-polymer accumulator) and wireless communication. The robot's 'trunk' consists of three parts, which are connected by compliant mechanics. The robot has six DC motors, each driving one effector. The drives are integrated in a chassis frame designed as a double wishbone axle.

2.2 Robust locomotion by a compliant trunk

The parts of the trunk and the chassis are rigid body constructions connected by compliant elements. The connectors between the parts of the trunk have two different main functions. Two parts of the trunk are connected with a DOF (degree of freedom) = 2 and hence they can relatively rotate in two axes (cf. fig. 2 right). The first degree of freedom (rotation α) is realized by the two bending rods (3) arranged in parallel orientation. The second DOF (rotation β) is realized by a revolute joint (4) with integrated viscoelastic elements (rubber) and thus elastic and damping properties.

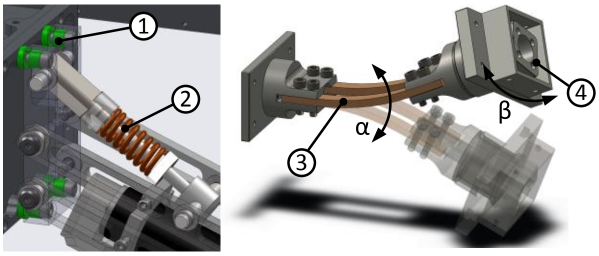

Fig. 2 Left: Compliant connection between the trunk and the chassis (elements (1)) and the suspension element for vertical shock-like motion (2). Right: Compliant connection between the trunk elements consisting of two parallel arranged bending rods (3) and a revolute joint with rubber elements

The connections between the trunk and the chassis are designed to have a shock-absorbing behavior (fig. 2 left). Rubber elements (1) are located between the trunk element and the mounting plate of the chassis construction. Additionally a suspension element damps vertical motions and allows a better adaption to unstructured terrain. The damping factor of this spring-damper-system is high, thus only damping and no swinging behavior could be observed. The high DOF of the robot leads to high ability for adaptation to the shaped ground. Actually, three different types of effectors are available: 1. wheels, 2. stiff hybrid-wheels, and 3. elastic hybrid-wheels.

2.3 Classic effectors

The wheel effector is designed for locomotion on flat and lightly structured terrain. The power needed for locomotion is very low, because of the low resistance of rolling. The movability in structured environment is limited, e.g. stairs and scree slopes are difficult.

The stiff hybrid wheel has three spoke-like elements made of POM plastic (polyoxymethylene). The material is very robust and can resist high mechanical loads without any brittle fractures. At the end of each spoke-like element, there is a buffer made of rubber. Those buffers damp the mechanical impact load and increase the traction. The movability on stairs and scree is very good. But on flat terrain, the mechanical impact on the effectors and thus the chassis as well as the gearbox and the DC drives is very high.

Fig. 3 Left: Different classic effectors are available for ROLV robot with a diameter of about 0.32 m. Left: Wheel effector. Right: Stiff hybrid wheel effector with three spoke-like elements

2.4 Elastic hybrid wheels

The elastic hybrid wheel combines the advantage of a high movability in structured terrain with a reduced mechanical load in comparison with a stiff hybrid wheel. During fast locomotion, the resonance effects are used for locomotion for reduction of the power effort. Therefore the spring factor of the hybrid wheel is adjusted to the mass of the robot.

The eigenfrequency f_{eig} of a mass spring system is calculated as follows

$$f_{eig} = \frac{1}{2\pi}\sqrt{\frac{c_{Robot}}{m_{Robot}}} \qquad (1)$$

Using formula (1) and aiming eigenfrequency $f_{eig} = 4.1$ Hz, a robot stiffness is calculated with an amount of $c_{Rob} = 7.63$ Nmm^{-1}. In tripod gate, the spring factor for one spoke-like effector is $c_{Eff} = 2.54$ Nmm^{-1}.

The elastic effector is modeled like shown in fig. 4 left as a serial configuration of two spring-damper-systems – one acting in radial direction, one in tangential direction. The dimensioning of the effector is done in several steps: analytic calculation of the dimension, optimization by FEM (finite elements method), and designing suitable for production.

The elastic hybrid wheel consists of four identical plates made of POM (cf. fig 4 right), which a stacked in a special opposite way. At the end of the effectors, rubber buffers are assembled like at the stiff hybrid wheel.

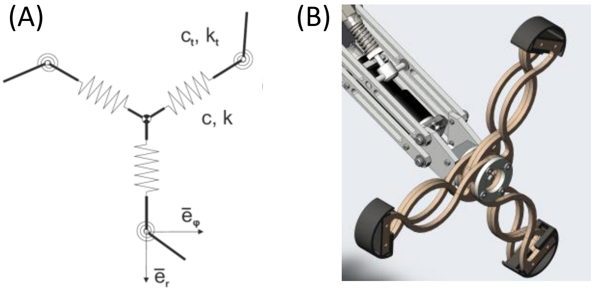

Fig. 4 Left: Spring-damper model of the elastic hybrid wheel, right: designed elastic hybrid wheel

The experimentally measured elasticity of the effectors is nearly equivalent to the aimed elasticity. In experiments, mechanical resonance was observed during locomotion at a determinate velocity of the robot. Further experiments will be done soon to quantify parameters and to make some energy balance analyses.

3 CONCLUSIONS

An elastic hybrid wheel was developed for a hexapod robot using resonance during locomotion. It could be observed, that the mechanical load is reduced during the impact of the elements of a hybrid wheel and that a resonance appears at a determinate velocity of the robot. Whether a reduction of the power is achieved, has to be verified in further experiments.

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