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SENSORY SYSTEM FOR THE DETERMINATION OF THE STEPPING FORCES OF MOBILE ROBOTS

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***Abstract*—**The mobile robot is a real interesting element in research. The stepping robots present interest for the quality that they can show on the hilly ground. The movement in a certain pace of a bipedal robot demands the achievement of a dynamic that imposes them a certain balance. The sensory system associated with the bipedal robots must ensure the transfer of information to the execution elements in real time. In the paper, the author presents a strength sensorial system attached to the stepping robot’s sole. The paper presents the constructive shape of the sole and of the sensory strain cells. The sole is articulated and allows the robot to realize a rolling-like leg. The information sent by the sensory system that is part of the robot’s leg are used to detect the contact between the leg and the ground’s surface, determining the position and the balance of the robot.

***Keywords*—** robot, biped, walking, sensor, force.

I. Introduction

THE mobile robot is a real interest element in the research domain. The stepping robots present interest for the quality that they can show on the hilly ground.

In the past years, the development of sophisticated biped walking robots has increased. There are presented a research project in the realization of a biped robot that is able to walk dynamically stable on even and uneven group and around curves, Löffler, Gienger, Pfeiffer [1], Vucobratovic [5], Westervelt and Grizzle [6]. It is also planned to realize a fast dynamically stable walking motion as well as slow jogging with flight phases. In comparison to the industrial robots which, in general, are skillful arms capable of ensuring a precise positioning of an object, the stepping robots have as principal port a stepping vehicle composed of body and legs with more than three degrees of freedom (DOF) which ensure the body’s support and the locomotion function. The legs can be: in the support phase – phase in which the leg is in contact with the ground, and the body is moving or not in relation to the stepping shadow – or in the transport (stepping) phase – phase in which the leg is not on the ground, but it is moving in relation to the body. The stepping locomotion ensures legs adjustment to the ground, each step made ensures the continuation of displacement, stability optimization and the independent body displacement with the ground configuration. The robot can move on surfaces with different settings. In any situation, the robot’s movement, that is achieved step by step allows for stability. One of the most important characteristics of the future robots is the mobility, Glocker [2]. The majority of the research about stepping biped walking robots focus on the pre-generation of the steady step trajectory or on equilibrium and dynamic control. Recently the techniques had been developing in the generation direction of on-line stable step trajectory mixing the stepping pre-generates cast. The robot “Johnnie” is equipped with 17 joint, Löffler, Gienger, Pfeiffer [1], Vucobratovic [5]. The leg of the bipedal robot has in its kinematic structure three joints - two joints at its ankle and one in the knee. The robot’s body has a mobility that is placed on an axis in a perpendicular plane on the body’s structure. Compared to robots with wheels, the biped walking robots have the ability to cross the obstacles by stepping above / on them. So, for the barriers avoiding technique strength sensors implanted in every foot can be used. These sensors can help the robot’s equilibrium by giving information concerning the ground’s nature.

The paper shows a strength sensory system attached to the stepping robot’s sole, as seen in figure 1. The paper presents the sole’s constructive form and the sensory strain cells’ constructive form. The robot’s sole is articulated and allows the leg’s displacement on the contact surface. The information regarding the contact points of the robot’s sole can be used to determine the ground surface and allows for the movement to be done under balance.

II. Sensorial System for Pressing to Force

The biped robot is equipped with two 3D six-ax forces torque sensors that are integrated into the foot, Löffler, Gienger, Pfeiffer [1].

The forces and torque on foot during a jogging motion have been determined with a specific multibody simulation program.

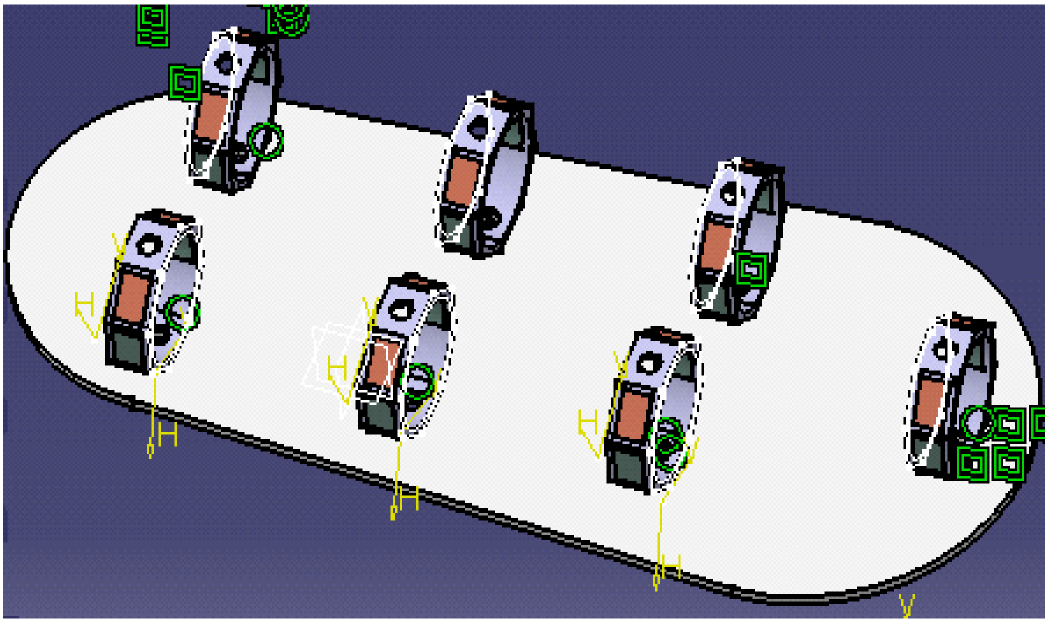

Fig. 1. The sensors positioning on the sole

The movement of the robot takes place gradually by means of the legs, during which the center of gravity is displaced from one leg to the other, the balance of the robot being achieved on the supporting leg.

For maximum stability margins, it can be selected to be in the middle of the foot area, for minimum lateral deviation of the center of gravity it has to be on the inner edge of the supporting foot.

The paper presents a sensory system (Fig. 1 and Fig. 5), which allows the determination of the robot leg and the support surface. Also, the constructive shape of the sensory system allows the position determination of the robot's center of gravity during walking time.

The system has in his configuration seven strength sensors which allow the 2D – forces determination in the respective measurement points. In Fig. 2 the constructive shape of the elastic element is presented and in Fig.3 the model of the in Fig. 4 it is introduced the applied model of the electro-resistive transducer geometric (TER) transducers of the strength forces which allows the forces determination on horizontal and vertical axis.

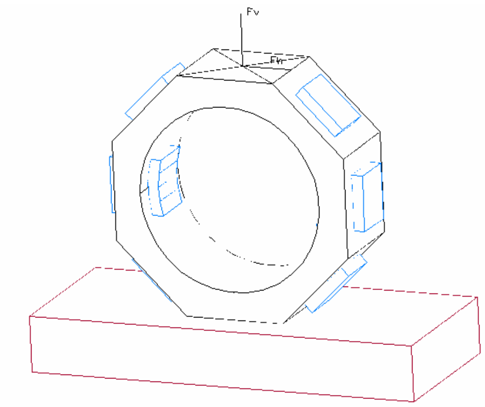

Fig. 2. The 2D sensor shape

has an orthogonal shape, being made out of an elastic steel with a certain elasticity and without mechanical joints. For strength determination of the two directions, TER transducers are applied to the elastic structure as seen in Fig. 3 and Fig. 4. $TER_1 – TER_4$ are connected in a Wheatstone bridge for the vertical force determination, $TER_5 – TER_8$ are plugged in a Wheatstone bridge for the horizontal force determination.

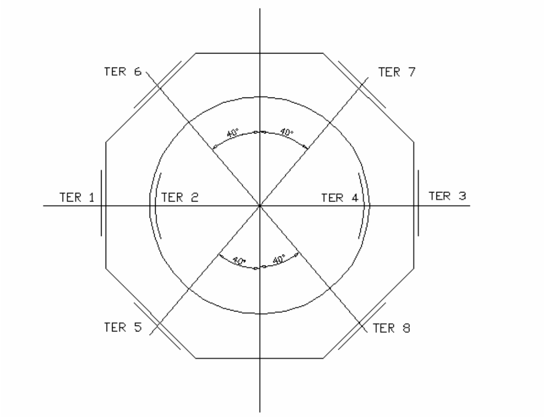

Fig. 3. The TER positioning on the elastic element

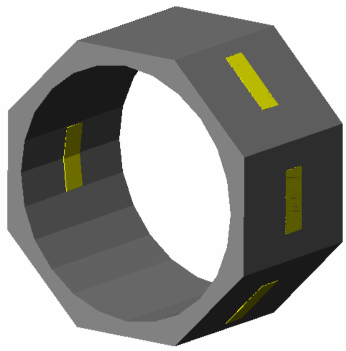

Fig. 4. The 2D-Sensor overall view

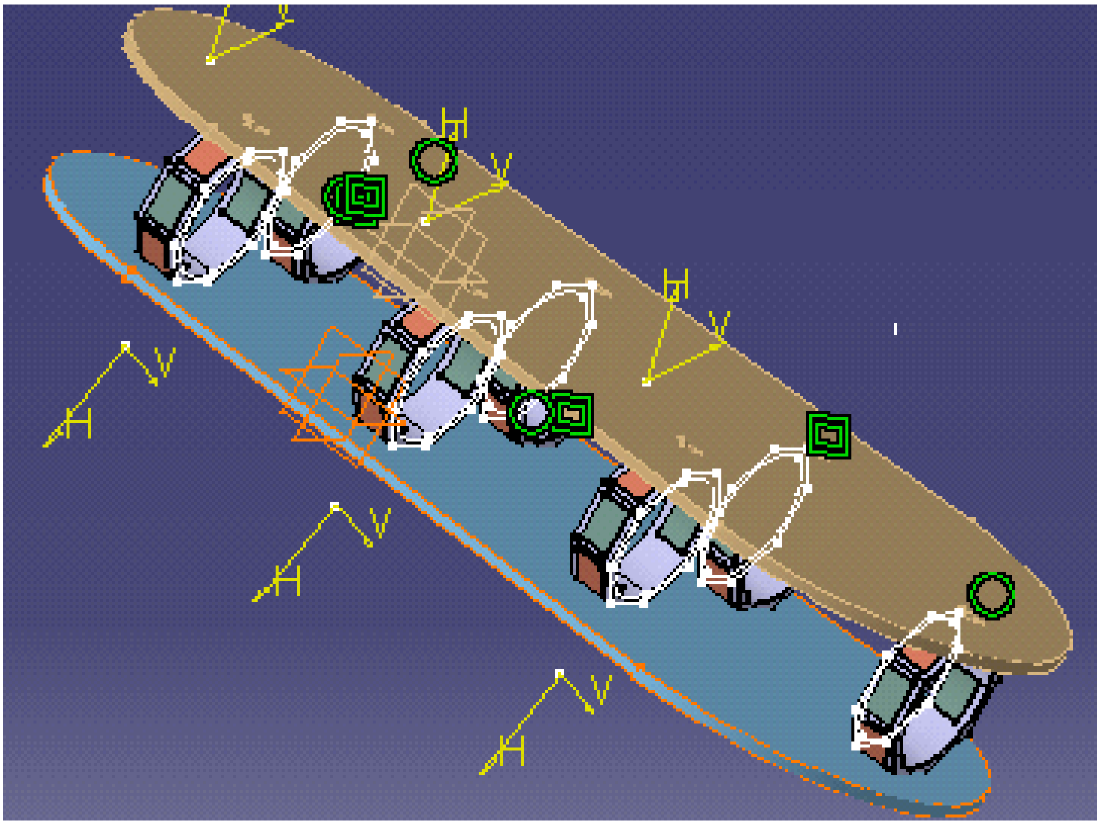

Fig. 5. Sole – sensory system ensemble

Particular emphasis has been put on the strains gauge application. The structure and shape of the elastic element allow the use of the strain gauges, in order to determine the forces in the two directions. The Wheatstone bridge connectivity enables the reduction of the temperature influence on the signal.

The 2D sensory system is fixed on the sole of the two-legged robot, giving information about the stepping. The sole is made out of two plates; one superior and rigid, on which is fixed to the foot ankle joint. The inferior plate is an elastic diaphragm over which an elastomer or rubber of a certain thickness is applied. The contact between the ground and the sole is made by means of the proposed sensory system. In this way, the interaction forces, between the biped walking robot and the ground with disturbances, can be determined. Through the obtained signals analysis the position of the center of gravity on the sole surface can be determined, which is absolutely necessary to the command of the biped walking robots' control.

III. INTEFASING DIAGRAM OF O FORCE

The auto-adaptive control of the bipedal robot enables the determination of the joints' position in the working space and displacement speeds. In this context, the design of the sensory system and connection schemes must be done such that the multiplexed signals can render the position of the robot's leg within the working space.

Depending on the normal force $F_{i,z}$ that is transmitted … e ground, the maximum transmissible

Torques $T_{i,x}$, $T_{i,y}$ and $T_{i,z}$, as well as the tangential forces $F_{i,x}$ and $F_{i,y}$ are limited by the friction coefficients.

While practical experiments show that the robot usually does not start slipping, the limits of the torques in the lateral and frontal direction T_x T_y lead to a small margin of stability. A lot of research has been done on concepts to ensure that these constraints are satisfied throughout the entire gate cycle. The "Zero Moment Point" theory is one of the most popular approaches to describe the constraints, Löffler, Gienger, Pfeiffer [1], Schneck and Bronzino [4].

Figure 6 presents the electric diagram for measurement balancing and interfacing of the sensor with detection tensometer, Stroe [3].

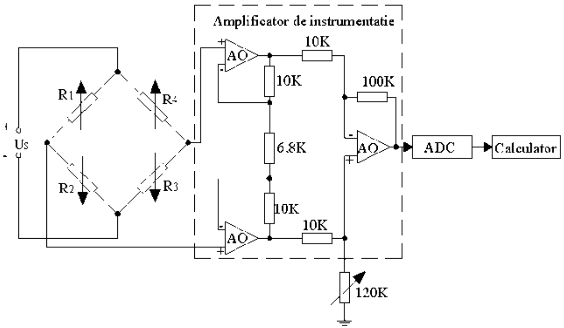

Fig. 6. Interfacing diagram sensors

The output of a Wheatstone bridge is a value with a magnitude of millivolts (mV) and it is, of course, an analog signal. For the sensor interfacing, analog-digital converters are used, that require the signal amplification for input areas of 0-2V. The inputs and outputs of the interface circuit must amplify the signal by 60-100 times, with slight deviation and large input impedance. The Wheatstone bridge balance and the signal amplification are achieved through an instrumentation amplifier.

The signal is transmitted to a digital analogous converter and further to a data bus at the computer for the active control of the sensors.

In Fig. 7 the sensorial system interfacing diagram for the system sensors is presented. The diagram includes two Wheatstone bridges noted with: F_V – for the slipping with resistive transducers TER1 … TER4 sensor and F_H – for the sensor.

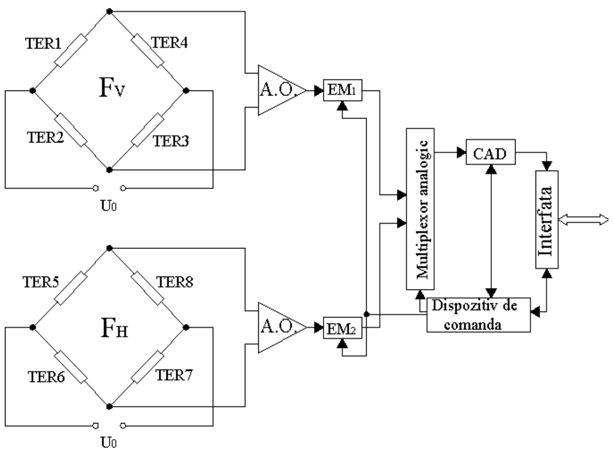

Fig. 7. Interfacing diagram of sensor system

The signals coming from the two Wheatstone bridges are processed by the operational amplifier, see Fig. 6. The signals obtained at desired parameters are transmitted to the computer interface through the agency of an analog multiplexer. There those signals are converted into digital signals by an analogue-digital converter.

IV. Conclusion

The sensorial system allows the determination of the position of the center of gravity on the sole surface when the biped robot walks. Knowing this position an efficient control can be achieved in the robot's position by transmitting the acting signals to the execution elements of the ankle joints.

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