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Inductive Displacement Sensor in Humanoid Robotic Application.

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In this paper a planar inductive displacement sensor is used to measure reaction force onto a foot of humanoid robot in order to determine the acting point of contact force applied on robot's foot. The construction of the sensor is presented in [1]. In [1] the sensor was developed for individual application as displacement sensor implemented in a mechanical system which ensured that coils were constantly parallel.

In this paper the aim is to implement the planar inductive sensor in the foot of humanoid robot. In each corner of the foot, the first sensor element, detecting vertical displacement (z-coordinate), is installed. Between sensor element in the left and right corner of the front part of the foot as well the back part is implemented the second sensor element, detecting the horizontal displacement (x-coordinate). A system such is robot's foot does not ensure parallel position between coils in sensor elements (Fig.1). Fixed coils (coils A) of all elements are mounted on a rigid part of the foot (Fig. 2). Short-circuited coils, coils B, are mounted on other rigid plate (made from dielectric), elastically mounted on the foot. Depending on how the foot touches the ground, the plate with short-circuited coils mounted on it, makes small 3D rotations.

For this practical application of the sensor it was important to examine if the characteristics of the sensor were the same when coils were not parallel. The measured and calculated results when coils B rotate around x-axes are shown in Fig. 3. It could be seen that there is small deviation between curves for different angle α between coil A and B which is negligible. It means that the sensor gives correct information about displacement in the working range of sensor elements irrespective to angular displacement of coil B.

In this paper the focus is on sensor element error introduced by assembling uncertainties and measuring nonlinearities of the sensor elements used for indirect measuring of the normal component of the force (the first sensor element [1]). The absolute error of the acting point determination is caused by the normal component of the force and horizontal displacement. Determination of the acting point of contact force is necessary for successive navigation of a two-leg humanoid robot. Results for absolute error detection of the acting point of contact force applied on the foot are presented on Fig. 4. The absolute error is the largest for the most critical case, when the real point of contact force is on the very edge of the back part or front part of the foot, $x_N = 0$ or $x_N = 300$ mm. The advantage of the sensor is that the working characteristics have complex shape and due to that, the measured points of contact force are out of the foot when the real point of contact force is on the very edge of the foot. In this case robot starts executing an algorithm for a fall avoidance behavior to ensure the stability during the walk. If the real point of contact force is farther from the edge of the foot then the absolute error is smaller. The obtained results showed that the error is acceptable which means that the sensor implemented in robot's foot gives correct information about the acting point of contact force.

[1] Mirjana Damnjanovic, Ljiljana Zivanov, Laszlo Nagy, Snezana Djuric, Branimir Biberdzic, IEEE Trans. on Magnetics, vol. 44, no. 11, pp. 4123- 4126, Nov. 2008

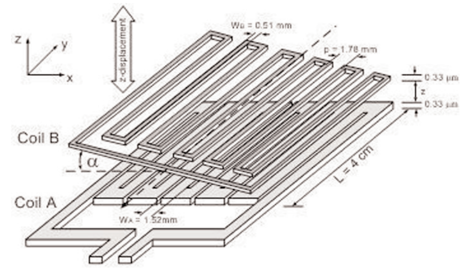

Fig. 1. Sensor element when coil B makes small 3D rotations

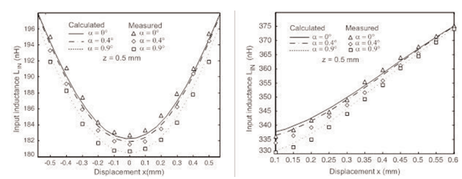

Fig. 3. Measured and calculated values of input inductance L_{IN} of the first (a) and second sensor element (b), for a different angle α and constant distance between coils z = 0.5 *mm*

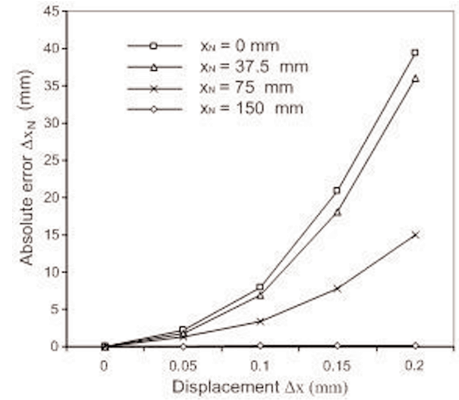

Fig. 4. Absolute error detection of the point of contact force applied on robot's foot

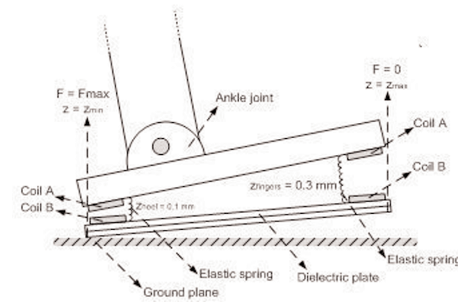

Fig. 2. Scheme of cross section of robot's foot. The length of the foot is 300 *mm*.