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Workshop on “New variable impedance actuators for the next generation of robots”

VIAM: Variable Intrinsic impedance Actuator for advanced Mechatronic systems

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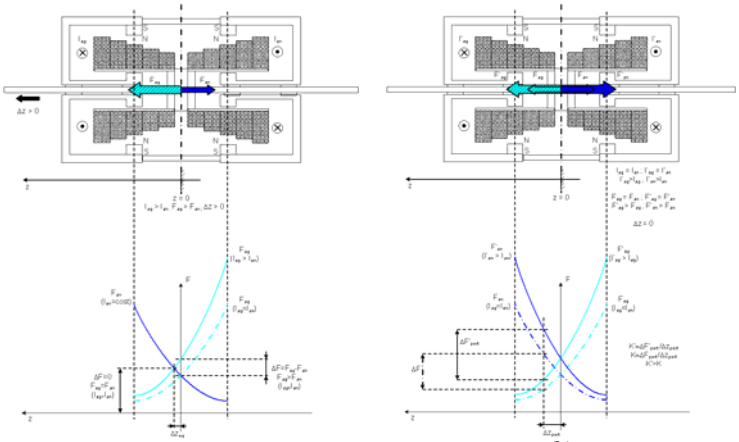
Introduction

This research focuses on the design and development of a brand new electromagnetic actuator based on the agonistic/antagonistic principle and make it possible to control position and stiffness separately. Two agonistic/antagonistic forces are internally generated by the interaction between permanent magnets and winding coils trough which separately controlled currents run. A first prototype has been developed in order to verify the feasibility and the effectiveness of the solution.

The actuation principle

It is common knowledge that humans regulate position and stiffness of their limbs by varying the rest position of the muscles attached to the limb after receiving neural activation signals. The stiffness changes thanks to the intrinsic non linear relationship between the muscle force and muscle elongation. In this idea [1] the actuator stiffness changes, regardless of the position, incrementing or decrementing the amount of currents in the coils, while the position can be varied by unbalancing the two currents. The principle can be applied both to linear and rotational actuators. This implementation regards the linear configuration. Two opposite forces are generated by the interaction between permanent magnets radially positioned and two groups of winding coils (hereafter called “actuation units”) which move axially. Each force is linearly dependent on the intensity of the magnetic field, the number of coil turns and the current. The relationship between force and displacement of each group of coils is properly established changing the number of turns of each coil. The gradient of the curve of the two units is controlled by the current; so that each unit behaves like a variable stiffness spring which is controllable directly by the current. Thanks to the particular configuration of the coils, each position reached by the translation unit is mechanically stable.

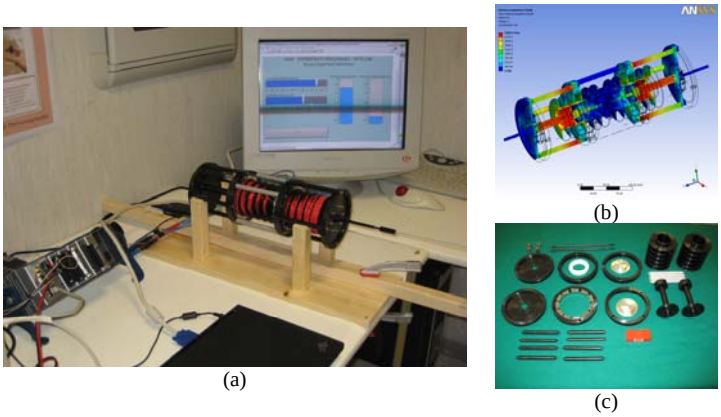


(a) (b)

Fig. 1 The translation unit moves towards the left/right if current increase in the coils on the left/right keeping the same stiffness (a); the stiffness increases if the currents in the coils symmetrically augment keeping the same position (b)

The prototype

In order to test the actuation principle an initial prototype has been designed and developed. Thanks to electromechanical simulations it has been possible to design the path of the magnetic flux and to calculate the interaction forces. Higher forces are obtained using ferromagnetic materials for the coil winding supports. Unfortunately simulations detected “the cogging” phenomenon; in order to reduce it, the support material has been changed but this led to a reduction in the maximum applicable forces. Future works regard the complete characterization of the first prototype, the decrease of dimensions and the optimization of actuation forces.



(a) (b) (c)

Fig. 2 The VIAM system: actuator, control board and PC interface (a); electromechanical simulations (b); actuator constitutive components (c)

[1] Electromechanical actuator structure – international application n. PCT/IB2009/001975 taken out on December 31st, 2009