Master thesis

Designing of a biphasic variable stiffness actuator for driving the 2-DOF anthropomorphic arm

Olena Hryshaienko

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Supervisor: Prof. Teresa Zielinska

Major applications in robotic systems today are expected to interact safely with humans and the environment. Variable impedance actuators (VIA) are actuators whose position and stiffness can be controlled independently. They are used in mechanical systems and robots when it is required to modify the stiffness/compliance of the joints during the functioning.

The research continues the work of development, implementation and use of a new technology of variable stiffness actuation (VSA).

The goal of the proposed research is to develop and test a variable stiffness actuator using biphasic media technology that would be able to replace the normal hydraulic cylinder in different machines in order to improve safety and comfort.

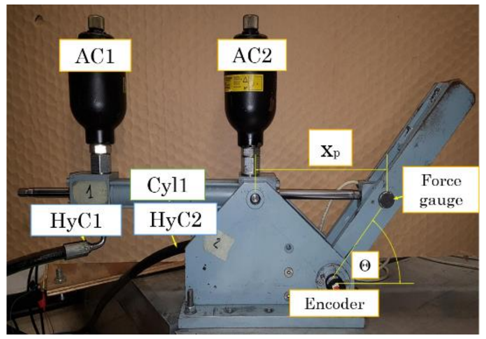

Figure 1: The view of the prototype.

The VSA was developed by prof. Matteo Zoppi and PhD. Jesus Hiram Lugo in UNIGE (Italy). The idea of the work of the BMVSA is following:

- The **gas fraction** (Nitrogen) works as nonlinear elastic element, providing variation of stiffness of the system due to pressure gas changes.
- The **liquid fraction** (oil) is assumed incompressible and used to provide pressure changes and motion to the output link.

2. Design optimization of the actuator

During this stage of the work, the new way of introducing the gas to the system was implemented by means of replacing the accumulators with the floating pistons. That allowed to significantly reduce the size of the actuator. After the concept was defined, the design of the VSA was presented as the optimization process. Following procedures were done to obtain the right dimensions of the VSA:

- Parameterization of the mechanism of the 2-DOF anthropomorphic manipulator.
- Calculation of forces and torques around the joints of the manipulator.
- Determination of the stiffness of the human arm.
- Associating the stiffness of the links with the range of stiffness of the VSA.
- Defining the values for the design parameters of the VSA.

3. Design optimization of the manipulator

Taking into account that the dimensions of the actuator had changed in compare to the one that were used in the model of the 2-DOF manipulator, and the fact, that the dimensions of links were not anthropomorphic (are not matching the length of links of the human body), in addition to the detected singularity in the shoulder joint VSA – the remodeling of the manipulator were done, and the new forces were calculated assuming that the mechanism (Hoeken's linkage) had changed with respect to the available stroke.

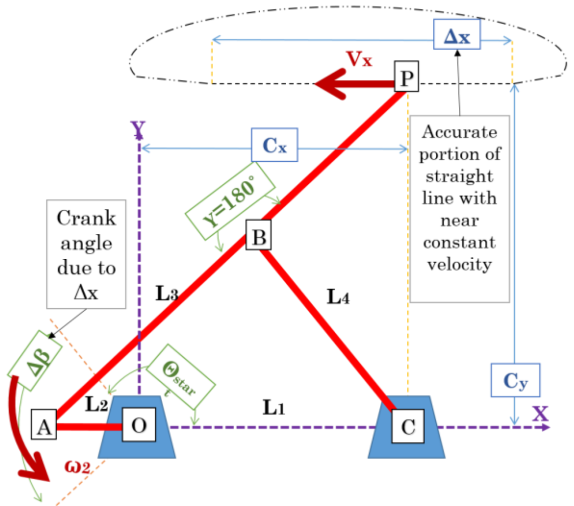

Figure 2: Parameterized Hoeken's linkage

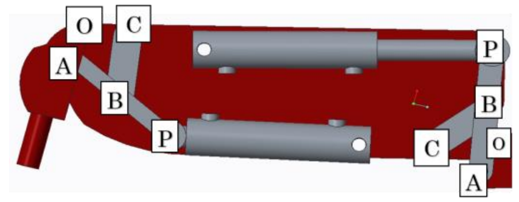

Figure 3: Parameterized mechanism for the shoulder and elbow joints of the manipulator.

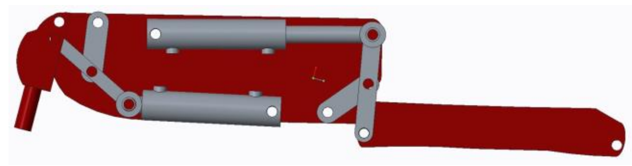

Figure 4: Updated design of the manipulator

4. Conclusions

After performing the experiment to determine the level of compliancy of the human arm and forearm, it was seen that it is possible to create the actuator that would be able to control the stiffness with the same range and allow the anthropomorphic manipulator to lift the weight up to 5.1[kg] being able to keep the weight straight in the extended.

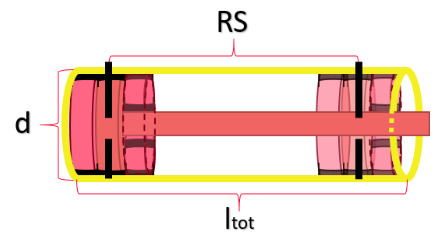

Figure 5: Design parameters of the VSA

To reach these results, it was proposed to develop the actuator with the updated dimensions:

- The real stroke *(the maximum stroke that is reachable with the lowest stiffness)*: $RS = 10$[cm].
- The diameter of the cylinder: $d = 3.2$ [cm].
- The total length of the cylinder: $l_{tot} = 14$[cm].

Nevertheless, simulation showed that the force required to drive the optimized mechanism of the manipulator is exceeding is $F = 730$[N] when only the kinematics of the mechanism is considered. So that the initial pressure in the gas chamber ($P = 11$[Bar]) becomes too high and the piston will no longer be having the required range of stiffness. For instance, the minimum reachable stiffness with respect to kinematics constrains $K = 13050$[N/m].