Improving the Controlling Design and Operation of a Finger Simulator

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ABSTRACT— ***Different kinds of simulators are available to test the finger (metacarpophalangeal) joint prosthesis devices before assembling inside the human body. Generally, those run by PIC microcontroller, which are critically designed and very large in sizes. Recently, different kinds of small, programmable and less energy consuming Circuit Boards have been used to run various electronic projects or systems. Additionally these small circuit boards are also valid for controlling the applications of the simulators. The School of Mechanical & Systems Engineering of Newcastle University, currently, is in possession of four pneumatic simulators which was previously used to test finger prostheses. Each rig has conducted in the vicinity of one hundred million cycles of flexion and extension. The aim of this project is to improve the design of controlling the finger simulator by using a programmable circuit board. The project has been divided into three different categories, designing, making and testing.***

Keywords— Metacarpophalangeal joint, Hall effect sensor, Simulator, Arduino Uno

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1. INTRODUCTION

Using prosthesis devices into a human subject is very common nowadays. Prior to using in human body, devices need to be tested properly to avoid any future injuries and problems associated with the prostheses. Similarly the related test instruments also need to be validated against surgical experiences before assembling inside the human body. The finger joint is a complex joint that contains of two different kinds of bone, Phalanges and Metacarpals. The finger joint is known as Metacarpophalangeal joint, is one of the less commonly implanted artificial joints. There are several types of prosthesis devices, used for Metacarpophalangeal joint. However, the Swanson silicon prosthesis has been extensively used as a "replacement of choice" for finger joint arthroplasty. The coherently used surface replacement material is Cobalt-Chromium (CoCr) and it constrains in the nylon stem holder (figure (1)).

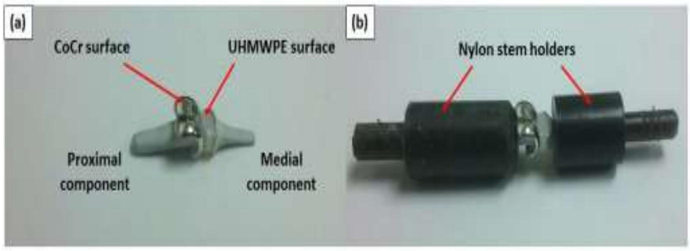

Fig. 1 (a): unconstrained prosthesis pair with surface labeled (b) prosthesis pair contained in nylon stem holders

For finger prostheses simulation there are very few simulators currently available to use. Most of the simulators, however, consist of flexion - extension and pinch tests. Currently, The School of Mechanical & Systems Engineering of Newcastle University is in possession of four pneumatic simulators which was previously used to test finger prostheses. Each rig has conducted in the vicinity of one hundred million cycles of flexion and extension, which has significant possibilities for improvement in several ways.

2. STRUCTURE OF THE SIMULATOR

The finger simulator is a machine with single station and the load across the simulator can be varied for flexion-extension and pinch, and flexion-extension speed can be varied along the lubricant and the temperature. The simulator is basically designed for MCP (metacarpophalangeal) prostheses, although it can be used to simulate any other joints prostheses with appropriate loads, motion and dimensions. It flexes prosthesis cyclically over a 90 degree range of motion, which represents the loading light in the time of flexion-extension. Next it applies a powerful static load to imitate pinch grip [3].

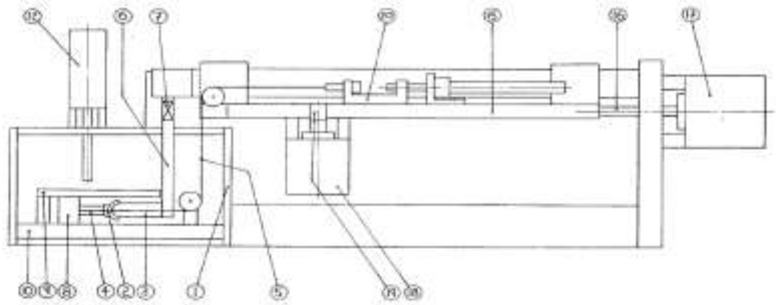

Fig. 2.1: Side view of the finger wear simulator [3]

In the middle of the simulator, there is a bath (1), where testing took place. The test Prosthesis (2) is mounted in two holders in the bath. One of these holders is representing the metacarpal bone (3), which holds stationary and the other one represents the proximal phalanx (4), which is oscillated against the action of the tendons (5). Both holders has shoulders, which helps to fix their locations. The metacarpal bone holder is mounted into the base of a square section cantilever (6) and load can be measured in two directions through eight strain gauges (7), which are mounted on the cantilever. The phalanges holder is held in a clamp and it rotates freely through the arc (8). It stands between a stainless steel base plate (10) and a polymeric arc piece (9). A moving pulley (11) has been attached to the base plate and which represents the volar plate and the metacarpal ligaments [3].

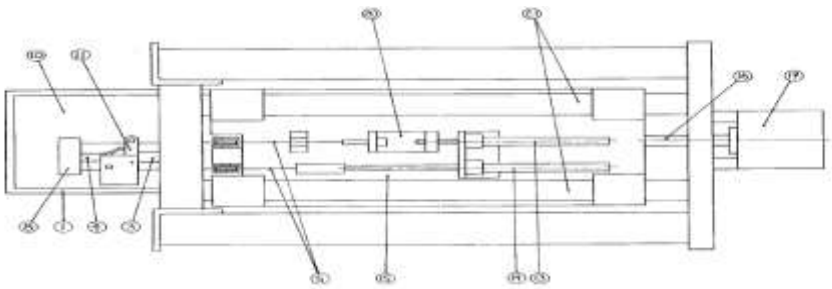

Fig. 2.2: Plan sight of the finger simulator [3]

A pneumatic cylinder (12) is also mounted on the bath along a stainless steel rod, which was acted as a ‘thumb’. The pneumatic cylinders provide the flexion-extension and pinch mechanisms, which are positioned above and behind the bath. Besides, pulleys guide the tendons from the bath to the pneumatic cylinders (two), which individually provides flexion (13) and extension (14). These cylinders are built on an aluminum slider (15) and connected by a universal coupling (16) to the large cylinder (17) at the rear of the framework [3].Along that, another pneumatic cylinder (18) is amplified as a ‘flexor stop fork’ (19), which is appeared across the aluminum slider. When the large cylinder (17) is activated the flexor adjuster (20) and pulled against the flexor stop fork. Two steel rods (21) each mounted within a pair of bushes allowed movement of the light aluminum slider during the activation period of the light cylinder [3, 10]. Previously this system was controlled by two large PIC micro-controllers, which are outdated. Along that, the controlling system also had lots of weaknesses. As example, it was too big in size; programming codes were unchangeable, consuming a lot of energy and very critically designed etc.

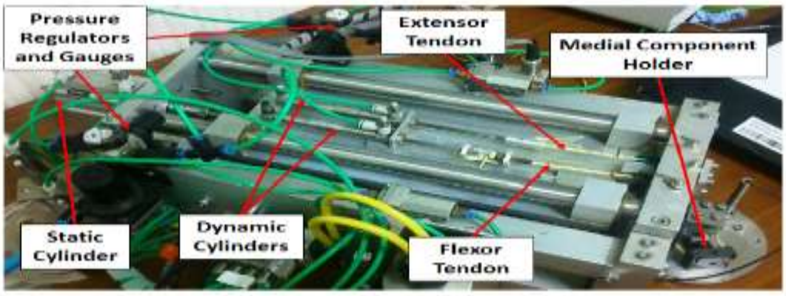

Fig. 2.1: The finger Simulator [2]

3. DESIGN AND SIMULATION

To design the controlling system of the simulator by using Arduino Uno Rev3, firstly, we made a logical flow chart to build the circuit and design\write the programming codes (Figure 3.1). After that, we designed and built the circuit according to the flowchart and a proper programming code for IDE software is written, which runs the Arduino Uno Rev3 according to the objectives of the project [7, 8].

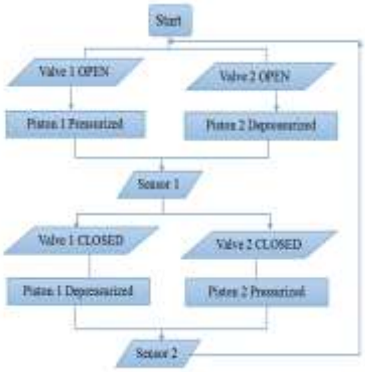

Fig. 3.2: Flow Chart of working procedure of the Finger Simulator

Before, practically working with the Arduino Uno Rev3, relay and the simulator, we try to draw the basic diagram of the circuit, where all the sectors have been mentioned along the Arduino Uno Rev3, Relay and simulator [8].

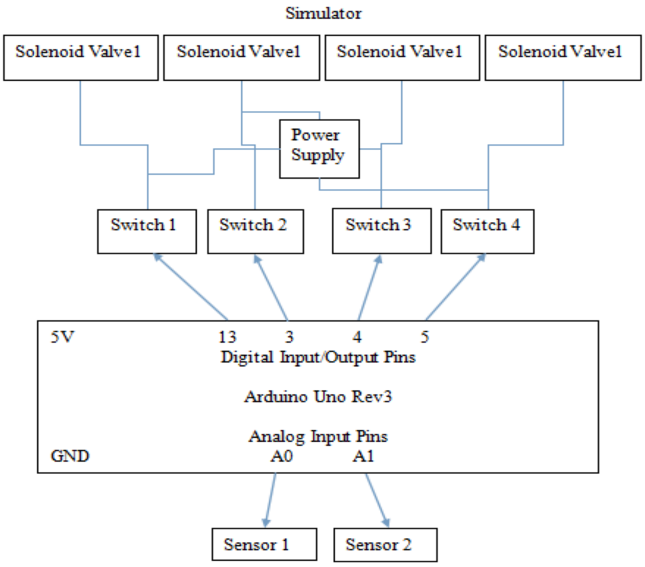

Fig. 3.2: Basic Circuit Design

Next, we build the preliminary design of the circuit, which is consisting of the sensors, 8-channel relay switch and the Arduino Uno Rev3. The following figure (3.3) shows the connected (wired) circuit board. Here, we also add a 24V power supply, which helps to run the simulator and through the 8-channel relay we try to control the simulator with the 5V Arduino Uno rev3.

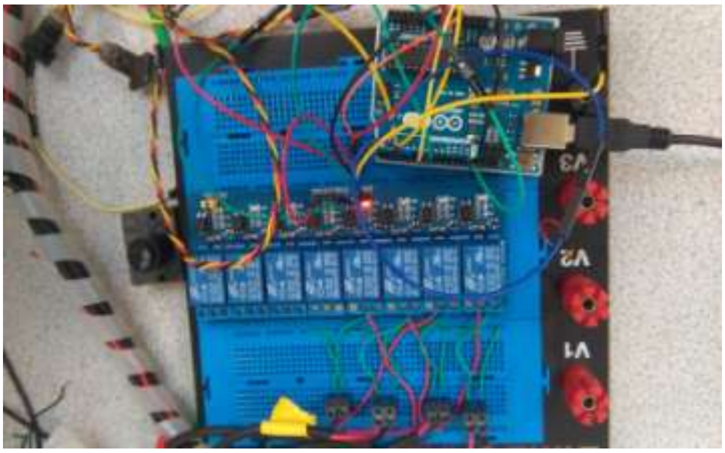

Fig. 3.3: Wired circuit, including the Arduino and the Relay

To sum up, it can be said that, the flow chart explains how the solenoid valves react upon the signals from the magnetic sensors and how it responses with the timer. Along that, a loop process needs to be understood properly.

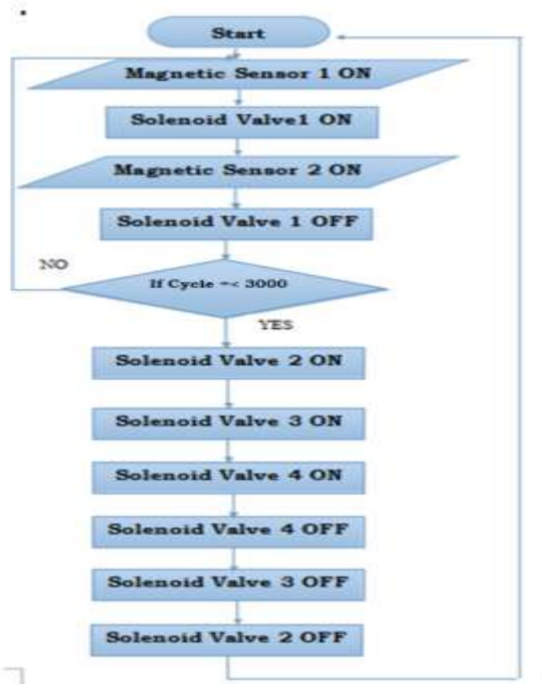

Fig. 3.4: Complete Flow chart to run the simulator

4. Conclusion

The main method used in this simulation system is using automation system to control and develop an appropriate design for the system to achieve the goal to build an advanced finger simulator. We accomplished the designing goals in three different steps, as power supply provides the energy, Arduino Uno Rev3 controls the system and the relay works as a converter to accomplish the predictable and correct outcomes. In the end, the programming requirements have been achieved and all the section wired together along the simulator to run the testing, with predictable and successful outcome. This Project can be useful for the manufacturers of different kinds of simulator or similar kinds of testing equipment, and also can be useful to control any systems with minimum space and that also can help to reduce exceeding use of energy and power, such as electricity. So, overall it could be a beneficiary project for laboratories, hospitals and manufacturing industries.

5. References

[1] Orthopod, (July, 2017). Finger Fusion Surgery (A Patient's Guide to finger Surgery) [Online]. Available: http://http://www.eorthopod.com/finger-fusion-surgery/topic/118.

[2] Dr. A. Naylor, S. C. Talwalkar, I. A. Trail and Prof. T. J. Joyce, "In Vitro Wear Testing of a CoCr-UHMWPE Finger Prosthesis with Hydroxyapatite Coated CoCr Stems", Mech. Sys. Eng., Newcastle Univ., UK, ISSN 2075-4442, Apr. 13. 2015.

[3] Joyce, T. J., and A. Unsworth. "The design of a finger wear simulator and preliminary results." Proceedings of the Institution of Mechanical Engineers, Part H: Journal of Engineering in Medicine 214.5 (2000): 519-526.

[4] Tamai, K., Ryu, J., An, K. N., Linscheid, R. L., Cooney,W. P. and Chao, Y. S. Three dimensional geometric analyasis of the MCP joint. *J. Hand Surg.*, 1988, 13A, 521–531.

[5] Weightman, B. and Amis, A. A. Finger joint force predictions related to design of joint replacements. J. Biomed. Engng, 1982, 4, 197–210.

[6] Joyce, T. J. and Unsworth, A. Wear of cross-linked polyethylene against itself. Proc. Instn Mech. Engrs, Part H, Journal of Engineering in Medicine, 1996, 210(H1), 11–15.

[7] Md. Faijul H., Sabrina H., Ayesha S., Md. Nasfikur R. Khan, "Smart Home Automation System Based on Environmental Monitoring System", National Conference of Electronics and ICT, Dhaka, 2017, pp. 34

[8] M. Nasfikur R. Khan, M. N. H. Pias, K. Habib, M. Hossain, F. Sarker and K. A. Mamun, "Bolte Chai: An augmentative and alternative communication device for enhancing communication for nonverbal children," *2016 International Conference on Medical Engineering, Health Informatics and Technology (MediTec)*, Dhaka, 2016, pp. 1-4.