Prototyping a Simple Small Smart Robotic Arm - Manipulator

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***Abstract*—In many experiments, it is frequently necessary to be able to perform several types of applications using simple manipulators for pick and place as in the case of sample preparation for different types of experiments. This paper describes a simple small and smart manipulator prototype using 3D printer which overcomes the need for small manipulations and handling applications. This manipulator will use pizo electric materials to perform the required operation. This manipulator will have only two links with small gripper and limited motion. The design will describe the motion and the required parts to get this small simple smart manipulator working.**

Keywords-Manipulator; Industrial, Design; Manufacturing; Robotic Arm

I. INTRODUCTION

Small Manipulators are designed to meet every possible small handling requirement and are ideal for applications which involve lifting and locating. The flexibility of the small manipulator's design will allow operators to control and maneuver the load in all directions. Loads may be rotated and manipulated manually or powered via a actuator. On the other hand, manipulators in this size have many more applications. All sorts of items that are too heavy, too bulky, too hot or too something for workers to safely and comfortably pick up and move. Manipulator design is a task that requires many applications [1]. Hence, the existing heavy rigid manipulators are shown to be inefficient in terms of power consumption or speed with respect to the operating payload [2]. Also, the operation of high precision robots is severely limited by their dynamic deflection, which persists for a period of time after a move is completed [3]. These conflicting requirements. In order to improve manipulator productivity, it is required to reduce the weight of the arms and/or to increase their speed of operation. For these purposes it is very desirable to build flexible robotic manipulators [4], [5]. Compared to the conventional heavy and bulky robots, flexible link manipulators have the potential advantage of lower cost, larger work volume, higher operational speed, greater payload-to-manipulator-weight ratio, smaller actuators, less energy consumption, better maneuverability, better transportability and safer operation due to reduced inertia [6], [7]. But the greatest disadvantage of these manipulators is the vibration problem due to low stiffness. [8]-[10]

This "Muscle Wire" is the perfect name for an alloy like a wire shape product because it is a unique type of wire that acts like the muscles in our bodies. Muscle Wire is an extremely thin wire made from Nitinol (a nickel-titanium alloy) that is known for its ability to contract when an electric current is applied. Although thin and lightweight, one of the most amazing things about Muscle Wire is that they can lift many times their weight and are able to do 100 times more work per cycle than the human muscle. This material is easy to use, small in size, operates silently, has a high strength-to-weight ratio, and is easily activated using AC or DC power. This technology is ideal where mechanics require minimization, such as electronic textiles projects, manipulators or nano-applications.

To activate muscle wires Either run current through or place these wires in hot water, and they can contract by 5%, and then expand to its full length again once cooled down, or when disconnected from the power source. Made up of equal parts nickel and titanium and developed by the United States Naval Ordnance Lab, (where the name Nitinol comes from). Because it is 50% titanium, this wire is much stronger than your average strand of wire. The reason Nitinol is able to expand and contract is because of its combination of crystal structures from the nickel and titanium metals. They react differently in high and low temperatures, making the wire soft and flexible when cool, yet firm and stiff when heated. The explanation for these structural changes lies at the atomic level. The shape changes are the result of the rearrangement of the crystal structures in the solid. When at room temperature, Nitinol can be bent into various shapes. Apply heat or electrical current and the atoms to arrange themselves into the most compact and tight fitted pattern possible resulting in the contraction of shape. The material has been deemed shape-memory because its crystal transformation is fully reversible. Once the temperature is lowered, it returns to, or remembers, its original shape. This cycle can be repeated millions of times [9], [10]

II. PRODUCTION OF SIII MAIPULATOR USING 3D PRINTER

The mechanism could be divided into two parts, the mechanical and the electrical part.

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A. 3D Printer

All the mechanical parts will be manufactured using 3d printers similar to the one shown in Fig. 1. In this paragraph small discussion about those printers will be presented. 3D printing is a process of making a three-dimensional solid object of virtually any shape from a digital model. 3D printing is achieved using an additive process, where successive layers of material are laid down in different shapes. 3D printing is also considered distinct from traditional machining techniques, which mostly rely on the removal of material by methods such as cutting or drilling A 3D printer is a limited type of industrial robot that is capable of carrying out an additive process under computer control. While 3D printing technology has been around since the 1980s, it was not until the early 2010s that the printers became widely available commercially. The first working 3D printer was created in 1984 by Chuck Hull of 3D Systems Corp.

Figure 1. 3D printer used in the manufacturing of the Mechanical parts

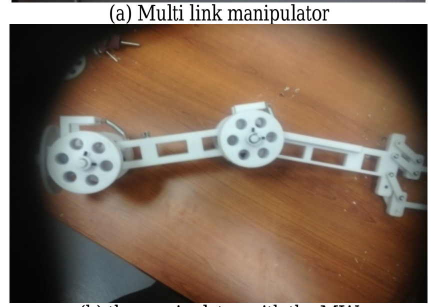
B. The Mechanical Part

The process of constructing the manipulator with hand shaped gripper from mechanical view is developed in simple form where they are produced using 3D printing as shown in the figures below.

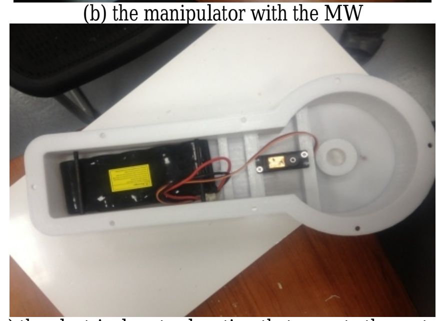
Figure 2. SIII manipulator

Fig. 2 demonstrates the simple manipulator, which consists from three links, the links connected together through nails. The motion of each joint is accomplished by number of muscle wires (actuator) and one elastic spring to return the moved arm back. three arms manipulator will add more flexibility to generate a motion. All the design procedures and calculations were done using Solid Works as shown in Fig. 3a to 3c.

(a) Multi link manipulator



(b) the manipulator with the MW



(c) the electrical motor location that operate the system

Figure 3. Different parts of the Manipulator

It is required to move each arm independently, and that may be through connecting each arm joint with independent pulley connected using MW.

C. Electronic Part

The electronic part of activation the muscle wire is not very difficult, but as the number of MWs used increases, the complexity of the electronic circuit will increase, and so on. Muscle wire must be activated with Pulse-Width-Modulation (PWM) signal (i.e. ON-OFF) to prevent the overheating case of the MW. In other ward, MW under activation must be putting under cycling (heating and cooling). Fig. 4 shows a schematic of the activation circuit of a single MW. The 555 integrated circuit U1, is a popular chip that contains over 40 transistors, resistors, and diodes. Turning its output (pin3) on and off according to the values of R1, R2, and C1, as showed by the following equation: $T_{ON}=0.69(R1+R2)\ C1$ $T_{OFF}=0.69R2C1$ The PWM signal is shown in Fig. 7. In this prototype a lot of MWs used to perform the desired function, and since each MW needs amount of current which is the recommended current required to activate the MW (sometimes current reaches 1 amp, and/or more depending

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on the length and cross-section area of the MW used) [10], driver used to supply the MWs. Number of power transistors may be a good choice. A microcontroller used to select the required MW(s) depending on the previous condition. It had been also designed the driving circuit that containing the microcontroller.

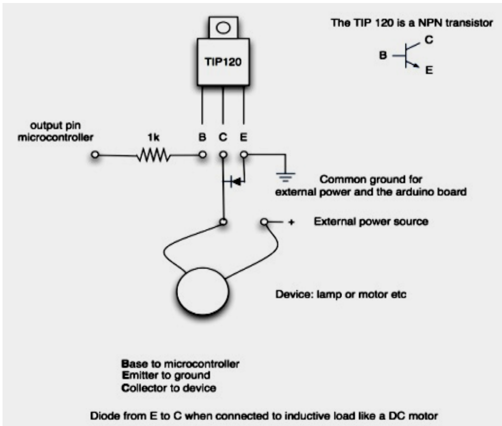

Figure 4. Activation of MW

D. Control

Any muscle wire with a given length has a resistance that changes with length (i.e. the resistance of the MW is a function of its length) [11], and since each MW with a specific diameter needs a recommended current to be activated, the voltage required changes with MW length also. That means a MW with a given length will contracts by a constant length (MAX. 8% of its original length), and this is a problem appearing in the control system, where to control the motion of the system, the input to the actuator (here MW) must be as a parameter, whereas here the input to the MW is a constant voltage (the recommended one to activate the MW). One of the proposed solutions to this problem is to connect several MWs have the same length in a series sequence and separated electrically.

The activation of one MW will cause motion of one link. To change the motion may be we need to activate two MWs and so on. To increase the accuracy and smoothness of motion, large number of MWs with respectively small length will be required. As a case study, four MWs with length 100-20 cm each and of the same diameter (100 micrometer) used to control the motion of the manipulator and gripper.. Since the motion of each MW is constant, then the control strategy that established here is by using ON-OFF algorithm.

III. MUSCLE WIRE

Muscle wire or (shape memory alloy) is thin wire when it's heated with hot water or an electrical current it will magically return to a predefined shape that it has been adjust to be remember.

It's called Nitinol (a nickel-titanium alloy), Nitinol stands for Ni (nickel), Ti (titanium), and Naval Ordnance Laboratory, the place where it was discovered in 1965. Also known as Smart-memory alloy (SMA) is an alloy capable of returning to a specific physical shape. It has special mechanical properties instead of deformity as the normal metals its contract like the muscle fibres. When it's heated above its transition temperature (the temperature where its contract). Typically 70°C internal molecular restructuring, it can contract by 5% of its total length, and then expand to its full length again once it's cooled down.

If muscle wire is used within the guidelines then obtaining repeatable motion from the wire for tens of millions of cycles is reasonable. If higher stresses or strains are imposed, then the memory strain is likely to slowly decrease and good motion may be obtained for only hundreds or a few thousand of cycles. The permanent deformation, which occurs in the wire during cycling, is heavily a function of the stress imposed and the temperature under which the actuator wire is operating.

Actuator wire has been specially processed to minimize this straining, but if the stress is too great or the temperature too high some permanent strain will occur. Since temperature is directly related to current density passing through the wire, care should be taken to heat, but not overheat, the actuator wire. The following chart gives rough guidelines as to how much current and force to expect with various wire sizes. The pulling force is based on 172 MPa, which for many applications is the maximum safe stress for the wire. However, many applications use higher and lower stress levels. This depends on the specific conditions of a given design.

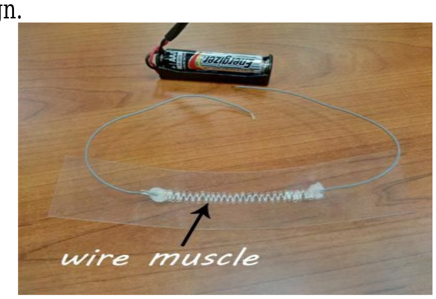

Figure 5. Muscle wire test using AAA 1.5V battery

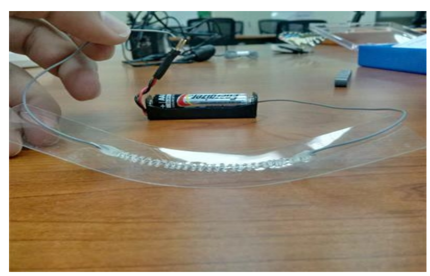

Figure 6. the wire start to contract

Figure 7. Full contraction

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Fig. 5, Fig. 6 and Fig. 7 showing muscle wire testing including the beginning of the contraction till it has been fully contracted.

A. Biocompatibility of Muscle Wire

Nitinol is generally a safe implant material as the FDA has approved many devices for long -term implant applications. Corrosion resistance the Nitinol alloys is highly dependent on the surface condition. Materials with a passive oxide layer, such as mechanically polished or electro polished and then.

B. Application of Muscle Wire

The contraction movement may be applied to any task requiring physical movement with low speeds. The small size, light weight, ease of use and silent operation allow Nitinol to re place small motors, stepper motors or solenoids. Spacecraft antennas, robotic arms, and artificial limbs are just a few of the hundreds of applications.

C. Weaknesses of Muscle Wire

- Energy efficiency
- Slow response times
- Yield strength low compared to steel
- Expensive to manufacture

IV. NOVELTY OF THIS MANIPULATOR

This manipulator does not have any motor. It is totally depend on muscle wires contractions. Although it is not that strong but it can be used for small and light duties. Our main goal was to use this manipulator in handling small and tiny stuff that is used in surgical operations. It can be used somewhere else where small and light things need to be picked and placed.

V. CONCLUSION

In this paper small simple smart manipulator is designed for simple applications like pick and place in small experiments. The manipulator used Pizo Electric materials in place of motors for operations. The result is small simple smart manipulator using very highly advanced materials and control systems for operation. It is light in weight cheap in cost simple in integration. At the end we achieved the requirement of manufacturing a prototype body of simple smart small manipulator, and we success in design it and printed it out. The result was in some parts better than what we expected and accepted in other parts but due to limit of time we would love to test our system with the muscle wire but we hope it will be on the next phase. After the design we found that the base cover was too heavy for the support material used in the 3D Printer that affect the quality of the printed cover so we replace it with a wooden cover. Also the remove of the supported material take much more time than what we expected. In the future work, we should reduce the total weight of the whole manipulator, increase the power supply. In the future work also we could double the length of the muscle wire in order to strengthening the contraction and flexion of the muscle which will give better movement for the joints and more flexibility for manipulator's extensions and contractions.

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