Design of Four degrees of freedom Manipulator with hand shaped gripper using Muscle wires

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Abstract—*Muscle wires or shape-memory alloy is an alloy that "remembers" its original, cold-forged shape: returning to the pre-deformed shape when heated. This material is a lightweight, solid-state alternative to conventional actuators such as hydraulic, pneumatic, and motor-based systems. Shape-memory alloys have applications in industries, medicine and aerospace. In This paper details of the design of an intelligent small scale manipulator for industrial applications (Pick & Place) will be designed using the new concept of muscle wires. Those wires will act like actuators but with less electrical consumption and lighter weight. The system will be designed using solid works . The manipulator will have four degrees of freedom and Hand Shaped gripper. It will be used in the local small industries for sorting or pick and plqace porpoises. The added value of this system will be to enhance the capability of the local Saudi industry in producing their own manipulators from off shelf components electronic document is a "live" template. The various components of your paper [title, text, heads, etc.] are already defined on the style sheet, as illustrated by the portions given in this document.*

Keywords—**robotics manipulator,musclewires, gripper**

I. INTRODUCTION

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 as shown in Figure 1.[1]
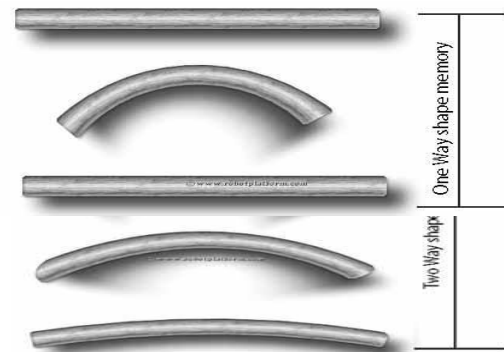

Figure 1 : Two common shape-memory effects are one-way and two-way shape memory (above)

This is an ideal material for making small, simple manipulator ! Compared to motors or solenoids, Muscle Wires have many advantages: small size, light weight, low power, a very high strength-to-weight ratio, precise control, AC or DC activation, long life, and direct linear action. These features let

you create whole categories of amazing new devices that would be difficult or impossible to do with anything else.

In recent years, significant efforts have been made by the robotics research community to simplify and improve the performance and control of manipulators. An interesting example is binary manipulators [2] In this concept, a manipulator is controlled by energizing actuators that can assume only one of two states ~''on'' or ''off''!. The joint level control is very simple. By simply triggering the given actuator in the system a discrete change in state is obtained. Often, the control does not require feedback sensors [3].

Future robotic missions will require robots to perform complex tasks such as scouting, mining, conducting science experiments, To accomplish these objectives, future robotic systems will need to work faster, travel larger distances, perform highly complex operations with minimum energy consumption. practical design concepts are required to meet these challenges.

In Designing such systems posses several complex challenges such as keeping the system lightweight,simple, accurate and choosing the number of degrees of freedom needed[4,5]. To address some of these challenges, we need to explore methods to reduce mechanical complexity introduced by conventional bulky components and large number of power wires[6]. The use of non-conventional components such as muscle-wires actuators is appealing. However, these introduce new limitations. Elastic joints have a finite range of motion and short fatigue lives[7,8].

This paper presents the design of a manipulator that is intended to meet these requirements and overcome the challenges. This manipulator , consists of compliant mechanisms with a numbers of embedded actuators and is a step toward practical implementation of muscle wires or binary systems in manipulator design and manufacturing[9] .

I. MANIPULATOR DESIGN

Most industrial applications of robot manipulators use position control. Examples include spray painting, spot welding and pick-and-place operations. In such tasks, the aim is to have the manipulator following a path (position and orientation) in free space with timing restrictions. Such a timed path is called a *trajectory* of the *end effector* of the manipulator. By definition, trajectories in free space do not introduce contact forces between the manipulator and its environment.

II DESIGN

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

A. *The Mechanical Part:*

The process of constructing the manipulator with hand shaped gripper from mechanical view is developed in simple form where they are designed experimentally depending on the trail and error.
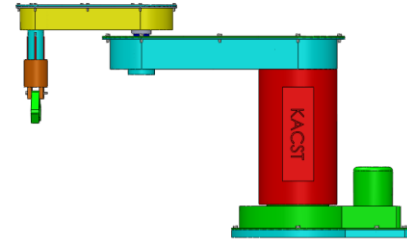

Figure 2 manipulator general design

Figure [2], demonstrates the first proposed simple manipulator , which consists from three links, The links connected together through nails. Each arm made of simple plastic. The motion of each joint is accomplished by number of muscle wires (actuator) and one elastic spring to return the moved arm back. With this configuration of the manipulator , a problem is appeared, that since the robot has the three movable arms, , and to make the motion more accurate the base arm will be operated using normal motor.The three arms manipulator will add more flexibility to generate a motion. All the design procedures and calculations were done using SolidWorks as shown in figure 3a to 3c.
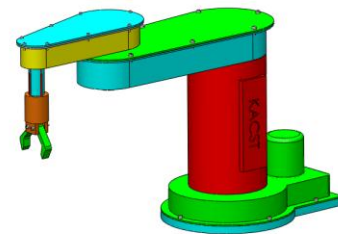

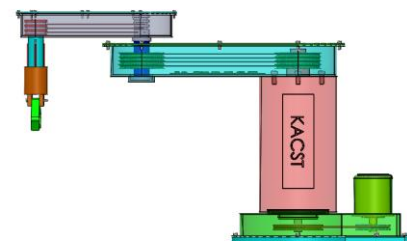Figure 3a :Multi link manipulator

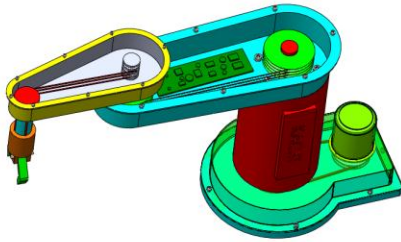Figure 3.b: the manipulator with the MW presented

Figure 3c: the electrical control location that will operate the system

It is required to move each arm independently, and that may be through connecting each arm joint with independent pulley connected using MW. Here plies are used to move the arms by observing the amount of motion or extraction of the MWs. Also each arm is connected to plastic spring and the spring connected to the joint or arm as the design required to return the arm to its original location. .. One problem developed here is that the independency of arms is unapproved, that is because there is a leakage developed between the bullies and the MW, and because of the miss location connection of plastic springs to. From the above discussion the problem appeared need solutions. The solution may be developed by building another arm and add more joints. The gripper of the manipulator will be selected and designed to look like a human hand as shown in figure 4.

Figure 4: Hand Shaped gripper

B. 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).
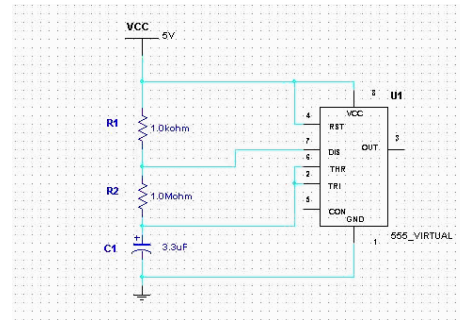

Figure 5: A Schematic of the Activation Circuit of a Single MW

Figure. 6. 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: $TON=0.69(R1+R2)C1$ $TOFF=0.69R2C1$ The PWM signal is shown in Figure [7].

Figure 6: Activation Signal

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 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..

C. Control strategy

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. All the operations of the MWs must be done and controlled using controller system and it must be controlled accurately and that is possible using a control program. Which is built in a microcontroller IC AT89C51 version using C language. To discuss the force generated on the proposed gripper, it must first to analyze the force generated by a single activated muscle wire. it is known that the recommended recovery weight for a single MW (which is generated from applying a recommended current) of 100μm generated about 1500 N when activated. Since the MWs of the proposed gripper are connected in series, the effort (force) therefore is duplicated simply through activation more MWs.[10]

III CONCLSUION

In this paper the design and implementation of a small scale manipulator with hand shaped gripper is presented using muscle wires as actuators instead of normal motors. The system will be designed using solid works and then simulated with ADAMs or MATLAB. The manipulator will have four degrees of freedom and a high movement flexibility. It will be used in the local small industries for sorting or pick and place porpoises. The added value of this system will be to enhance the capability of the local Saudi industry in producing their own manipulators from off shelf components.

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