Shape Memory Alloy Actuated Inchworm

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Abstract: Shape memory alloy (SMA) is a type of material that are able to return to its original shape.When subjected to appropriate temperature. The properties of SMA makes it suitable for actuation in robotics. When dealing with small size and weight of it. Especially when small size and weight are desirable. Shape memory alloy has many applications in bio-robotics such as Manta ray robot, Snake robot and fish robot etc. In this paper a SMA actuated inchworm is reported. The components used in the inchworm robot are the compression spring, shape memory alloys, plastic sheet, Crimps, Arduino board and ULN2003A and DC power supply. The designed inchworm robot mechanism has 2 plastic plates attached to glue. These plastic plates have negligible weight and compression spring is used for bias force .To assure better mechanical design of robot SMA actuator and spring are employed. When a signal is given from computer the power is transmitted from DC power supply, and supply SMA wire. Then current causes an increase in temperature of wire, as a result wire contracts and pushes the worm in forward direction.

Keywords: *Bio-robot, bias force Shape memory alloy and Inchworm*

1. Introduction

Most of the micro-structures are developed using SMAs, that changes with the change in temperature and stress by releasing energy [1]. The released energy can be used to start any mechanical components. Currently, SMAs are becoming more popular, because of its particular characteristics, such as high energy to weight ratio, smooth, no noise and biocompatible and simultaneous actuation and detection [2]. SMAs exhibit Shape Memory Effect (SME), which helps it to retain its original shape when deformed (heated or load applied). SME is produced by the thermo-elastic transformation between "Martensitic phase" (M-phase) at low temperature and "Austenite phase" (A-phase) at high temperature reported in [3] show in Fig: 1. There are number of alloys are present that exhibit such behavior. That includes Cu-Al-Ni (Copper-Aluminum-Nickel), Ni-Al (Nickel-Aluminum).Ni-Ti (Nickel-Titanium), Mn-Cu (Manganese-copper) and Fe-Mn-Si (Iron-Manganese-Silicon) [4].Present research has carried out to help in selecting the actuator for robotic inchworm [5].

Shape memory alloys (SMA) have distinct properties.

- Super Elastic behavior
- Shape memory effect.

1.1 Super elastic behavior

When a shape memory alloys in cold state (below As), metal can be bent or stretch with will hold these shapes, until heating on transition temperature. In the heating, the shape turns into its original shape.

1.2 Shape memory effect

- One way shape memory effect
- Two way shape memory effect

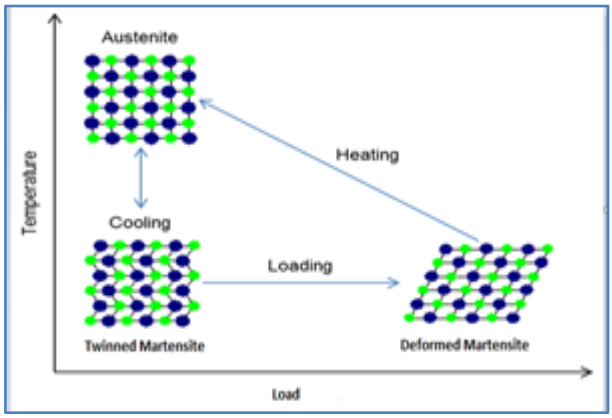

Figure. 1. Crystalline arrangement of SMA in different phases.

1.3 One way shape memory effect

It is a type of exhibition property that is used to convert to the desired shape only occurs in heating. i.e., memory is with the austenite phase.

1.4 Two way shape memory effect

The two-way shape-memory effect is the impact of the material will remember two different shape: one at low temperatures, and one in the shape of a higher temperature. i.e. memory is with both austenite and martensite phases.

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2. Related Work

The literature exit on understanding and the ability of the animals look forward to efficiently in a different environment normal propulsion system (such as wheel) failed [6,7]. The typical applications of bio-robots designed using SMA ranges. These robots have been developed by getting inspiration from locomotive insects and parasites. (such as leeches) [10].Ideally, the simulated moving worm will constitute a stage for enhancing the information of instruments controlling movement and observation capacities of these animals. During the search, earthworms squeeze push the front of the soil, other parts of the body as an anchor point. The front portions at that point extend as another anchor that helps pull forward segment behind them. The main components of segment body are longitudinal muscle and circular muscle: circular muscles of the contract, the decrease of segment diameter and length of the segment must be increased in order to make the above volume will remain unchanged. Similarly, when the longitudinal of the muscle to the contract, thus reducing the length of the segments and segment diameter must will increase. The author outlined a earth worm with four modules which can be driven freely as designed with a frequency of 0.5 hz. Each module is incited by at least one SMA springs whose setup has been composed off, keeping in mind the wiring issues and upgrading working frequency. The robot is secured by a formed silicone material which can be utilized as a stage to embed minor legs for getting differential erosion conditions. Initial tests exhibit that the earthworm like-miniaturized scale robot model can move with a speed of 0.22 mm/s show in fig: 2 [11, 12].

Figure .2. Artificial Earthworm Prototype

The Portability of miniaturized scale robot: The proposed miniaturized scale robot framework is made out of an actuator with SMA spring, silicone cries, remote control framework, remote power supply (battery) and framed body structure. Although, the robot can be modify according to the required particulars. After the survey and investigation, we discover that the miniaturized scale robot can move itself and can be created effortlessly. Like an earthworm, the robot can go on uneven, elusive and adaptable condition [13].In this paper the M. M. Kheirikhah has designed a biomimetic robot like earthworm for endoscopy in which two SMA wire are used as actuator. The dynamic model of the system was been simulated based on different electrical inputs. The accuracy of the response of the robot to the preferred position is to review and compare result with other [14].Endoscopic technology development, diagnosis and treatment of gastrointestinal (GI) diseases [15].Endoscope is a thin tube devices used for the non-invasive inspection, tumor or internal cavity and canals. [16].A locomotive is based on the principle of biomimetic earthworms is to use the higher flexibility of Gastrointestinal [17].

3. Methodology

3.1 Material

The components used in the inchworm robot are the compression spring, shape memory alloys, plastic sheet, Crimps, Arduino board and ULN2003A and DC power supply.

3.2 SMA Wire

Shape memory alloy (SMA) are smart alloys, after when deforms for example when current and load is applied, it contracts; and then comes back to its pre-defined shape.

Specification:

SMA wire = 0.25mm

Cooling time = 0.18sec

Heating time = 0.15sec

Resistance = 36.25ohms/meter

3.3Arduino Board Mega 2560

Arduino is an open-ware computing platform, which is easy to download and can be used for writing C++ codes for a simple detachable micro-controller board that comes in different modules, here we used Arduino Mega 2560.

Specification:

Operating voltage = 5 V

Input voltage = 7-12V

Input voltage = 6-20V

Digital I/O pins = 54

Analog input pins = 16

3.4 ULN2003A

The ULN2003is a Monolithic high voltage and high current Darlington Transistor.

Specification:

500mA rated Collector Current (single output)
High voltage output: 50V
Input compatible with a wide range of types of logic.
Relay Driver Application

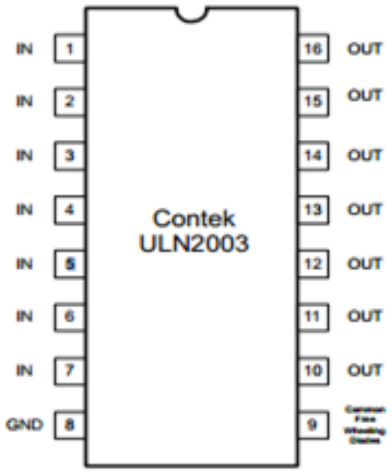

Figure. 3. Pin Configuration

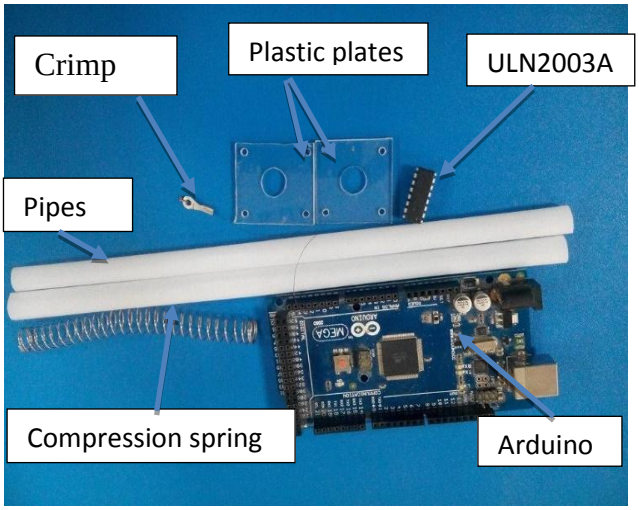

Figure.4. Prototype Components

4. Result and Discussion

4.1 Construction

It comprises of two plastic segment cutting shapes rectangular and drill at center for frame of spring and the passage of the SMA actuator as shown in the fig: 5.we use a non-conductive insulation plastic straws between the spring and actuator. They can also prevent spring from the bending. Utilize very light material. Crimps are attached the ends of the two parts of the adjusted actuator length which has bias load of spring.

4.2 Driving Circuit

The body of earthworm consist of section. In each section, with the exception of the first and last, one of the small setae also called as bristles that helpthe worm to move on the ground.The worm is scrawling stretch to push the back-forth and the contracting to pull the hind part. In fig: 5 show the structure and mechanism for the locomotive inchworm. This mechanism is a simple and effective. The front serrated aluminum sheet contract surface and the back body slides forward when actuators is shrunk by heating. After the contraction of the actuators, deformation energy stored in the spring response. At that time contract of the aluminum sheet, contract the surface and the front body slides forward.

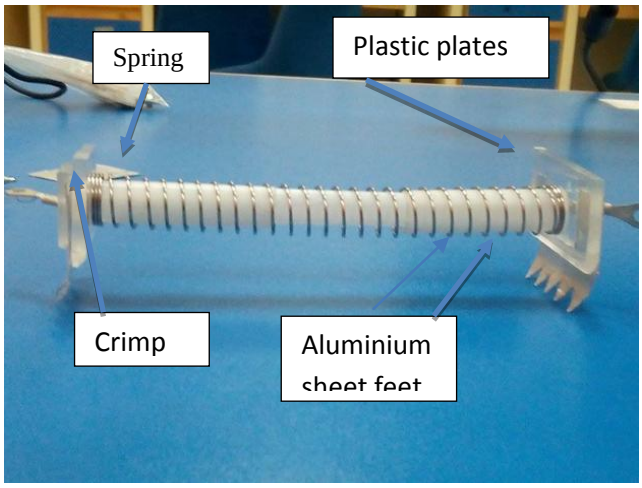

Figure. 5. Inchworm prototype

An ULN2003a is a high voltage, high current transistor array. The IC is used when driving a wide range of loads. The drivers can be parallel for higher current capability.

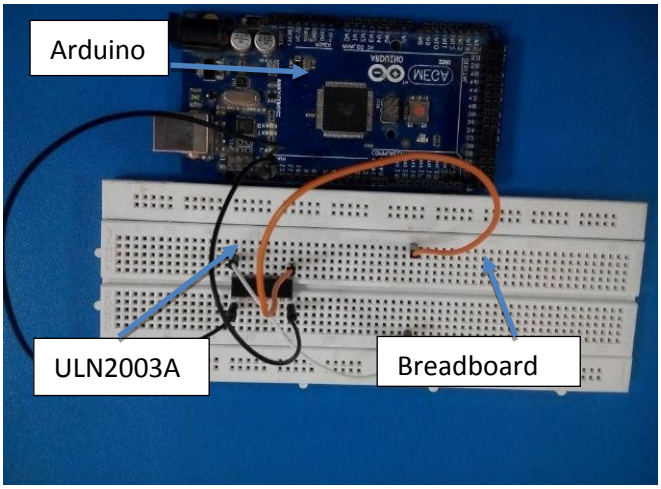

Figure.6. Circuit using ULN2003a IC and Arduino

The circuit shown above using ULN2003a power to Dc voltage supply. Which Arduino cannot supply. In other words ULN2003a amplifies signal of Arduino.

CODE

```
Void setup ()

{

// initialize digital pin 13 as an output.

Pin Mode (13, OUTPUT);

}
```

```
Void loop () {
  Digital Write (13, HIGH);
  Delay (1000);
 Digital Write (13, LOW);
  Delay (5000);
}
```

This program displays 13 pin is activated for 1 seconds and inactive for 5 seconds.

5. Conclusion and Future Work

In this research paper the artificial inchworm with SMA actuator was designed. The SMA actuator is used to start this mechanism is required. SMA actuator requires force to actuation. So, we utilized the pressure of spring for inclination constrain on account of plastic plates having insignificant weight. This earthworm like bio mimetic robot was achievable because of control framework and batteries in the smaller scale robot's body. To achieve this Bio-mimetic robot mechanism we completely perceived the real insects and worm movement. The worm's moving mechanism made things easy to design and fabricate it. The proposed bio-mimetic earthworm like robot is basic yet viable to go in limited and unpleasant condition, for example, human stomach related organs, twisted long pipeline and etc.

- SMA based springs can be all the more proficiently utilized for more stroke length when contrasted with wire actuator.
- To design a mini control system and batteries for this micro robot.
- We can attach camera to see and get information of the danger place.

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