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Implement of Shape Memory Alloy Actuators in a Robotic Hand

This paper was conceived to present the ideology of utilizing advanced actuators to design and develop innovative, lightweight, powerful, compact, and as much as possible dexterous robotic hands. The key to satisfying these objectives is the use of Shape Memory Alloys (SMAs) to power the joints of the robotic hand. The mechanical design of a dexterous robotic hand, which utilizes non-classical types of actuation and information obtained from the study of biological systems, is presented in this paper. The type of robotic hand described in this paper will be utilized for applications requiring low weight, power, compactness, and dexterity.

1. Introduction

Several unique and fascinating multi-degree-of-freedom robotic hands have been developed over the past twenty years, primarily using traditional means of actuation. Though there are many robotic hands, there are only a few using a new approach to classical robotic hand power.

Possible applications for the robotic hands include maintenance work in hostile environments, medical micro-manipulators, and undersea operations.

Two other SMA actuated hands are a biomechanic robot hand and a Fingerspelling Hand. The biomechanic hand is a prototype that imitates the human hand in shape. This is a five-fingered hand utilizing four Flexinol NiTi wires per finger, which are connected on the upper and lower part of the finger's body on both sides. The purpose of this hand is for flexible manipulation. The Fingerspelling Hand presents data from a computer one character at a time using a fingerspelling alphabet, which is read by the user placing their hands on the device. Companies that developed these kinds of robots are Hitachi Ltd., Oaktree Automation.

The hand has a forearm attached that houses the Flexinol wires acting in parallel, providing flexion and extension, and abduction and adduction antagonistically. This hand serves as a tactile communication aid for deaf-blind individuals [3]. Though there has been much research accomplished on SMAs, there is still a need for new design methodologies and paradigms for lightweight, practical hands for robotic systems. It is believed that the key to satisfying these objectives is via the use of smart materials, such as, Shape Memory Alloy artificial muscles. The advantages of Shape Memory Alloys include, their incredibly small size, volume and weight; their high force to weight ratio; their low cost; and their anthropomorphic behavior. Their limitations include: the large length of wire required to create significant motion, limited life cycle, non-linear effects such as hysteresis phenomena, and bandwidth and efficiency restrictions. It is proposed that the novel design methodology and prototype fabrication discussed in this paper will aid in the advancement and the development of human-like muscle actuators for assistive robotic devices and practical robotic systems.

2. Analysis.

The aim of the future researches is to design and fabricate an active robot hand, which allows smooth and lifelike motions for anthropomorphic grasping and fine manipulations. The robotic hand will have active robot finger with a shape memory alloy (SMA) wire actuator embedded in the finger with a constant distance from the geometric centre of the finger. The mechanical properties of the bending part will be investigated. Also, another aim of the research will be to evaluate the control system on the base of resistance feedback, in order to obtain in the final a robot hand with three fingers capable after specific experiments to demonstrate its performances.

Researched Shape Memory Alloys (SMA) designs in general, looking for such things as different actuation of the wires themselves, other ways to showcase the use of SMA wires.

In the field of robotics, the use of memory-shape alloys (MFA) can be planned to obtain optimized solutions of actuation. These alloys indeed present interesting prospects for profit of weight and volume compared to traditional actuators such as the electric or hydraulic jacks. Moreover, the actuator in MFA also constitutes a part of structure for the device considered the case of application studied relates to the use of an actuator working in inflection and presenting properties of double ratchet effect smell (EMDS). Initially, a preliminary dimensioning has to be carried out starting from a schedule of conditions describing the efforts in particular, displacements and the temperatures wished It is a question, then, of manufacturing the prototype parts and of defining the conditions of the treatment of education of alloy. This treatment which consists primarily of a thermo mechanical cycling is essential to confer on the MFA properties of double ratchet effect feel, i.e. to obtain two distinct geometrical configurations for two different temperatures. The realization of the treatment of education and the tests of operation on plates in MFA were carried out on specific machines the results obtained show that the amplitudes of deformation in inflection are limited to 1,8% to the maximum in the two directions in EMDS, and one notes light a diminution scale of displacement after several cycles of operation. The best performances are indeed obtained double memory feel assisted (EMDSA), by using a return spring which allows the reconditioning of the plate in MFA during each cooling. One obtains in this case, of the amplitudes of deformation of about 3% associated significant efforts during reheating. Moreover, the stability of the behavior can be checked on several consecutive operations.

The four major areas of research /comparison of the research are determined to be:

- Actuation
- Transmission
- Finger design
- Tendon attachment

Two potential issues that may arise during execution will be difficulty maintaining an accurate and consistent muscle/finger interface, as well as the inability to sustain proper joint relation while reducing overall interface dimensions. Considering the many difficulties associated with designing a robotic hand, the project will be consistently modified and revaluated to achieve the overall project goals.

The total size of the actuators must be reduced to allow continued development of robotic hands modeled after human hands. One current solution is to copy the muscle/tendon system using SMA wire. Considering the close similarities to human muscle fibers, SMA wires can be easily and effectively applied in actuators.

3. Design of the Actuator.

The characteristics of a shape memory alloy actuator system can be divided into three groups, namely the thermal property (TP), the material property (MP), and the geometric property (GP). The simulator is designed to model each group and together the overall behaviour of the system.

The overall system can be described by a constitutive equation

$$G(TP, MP, GP, current, stress, strain) = 0, \qquad (1)$$

just as shown above.

If sufficient input variables to function G are specified, the relation for the rest of the variables is determined. For a specific SMA actuator, the parameters related to TP, MP and GP are fixed. Therefore, $G = 0$ may be used to characterises the input-output relationship of the system.

Most conventional models deal with this relationship since it is important for controller designs. But when designing a specific actuator, stress, strain and some other actuator parameters are given as specifications, while the remaining parameters are to be determined to satisfy the requirements. A particular common version of this problem is to design a SMA actuator given stipulations such as force, stroke, size and material.

Shape memory alloys exhibit different mechanical properties at different phases. The highly non-linear characteristics of SMA create difficulties for both modelling and control.

4. Conclusion

By producing and testing a robotic hand, starting from the actual stage of researches in this domain, in order to obtain faster and more accurate response, can achieved better design and implementation. We are planning to design and construct a new test rig with force sensors for measuring the stress on each SMA elements. Using data from the force sensors, we intend to implement better control systems for SMA actuators.

Also, simulating the shape memory alloy actuator systems can predict the current-stress-strain dynamics of a NiTi shape memory alloy high-strain actuators. The simulator can be also used to design geometries of the proposed SMA actuator under specifications such as force, stroke, size, and speed.

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