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Artificial muscle manipulator

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Abstract

The aim of this project was to build robot manipulator with a thermal artificial muscle. In the end a slow manipulator with one degree of freedom has been built.

1 Introduction

The aim of this project was to build a simple artificial muscle manipulator. Artificial muscles were supposed to be made out of fishing line and sewing thread twisted together [1]. This kind of muscle contracts when heated.

2 Muscle structure

2.1 Tested approaches

2.1.1 Replacing sewing thread with copper wire

This composition did not coil properly and copper wire broke during rotation.

2.1.2 Replacing sewing thread with silver coated sewing thread

This solution was proposed in video published by University of Wollongong. Composition coiled irregularly with many nucleation points, the muscle did not work in the end.

2.1.3 Muscle woven with copper wire

Copper wire was to stiff to be woven properly,

2.1.4 Muscle woven with styrofoam cutter wire

Wires used for cutting styrofoam have ressistance of couple of ohms per meter and are able to work in temperatures as high as 1300 °C. This approach had the same issue as the previous one. Additionaly short circuits occured due to no issolation on the wire.

2.1.5 Muscle woven with silver coated sewing thread

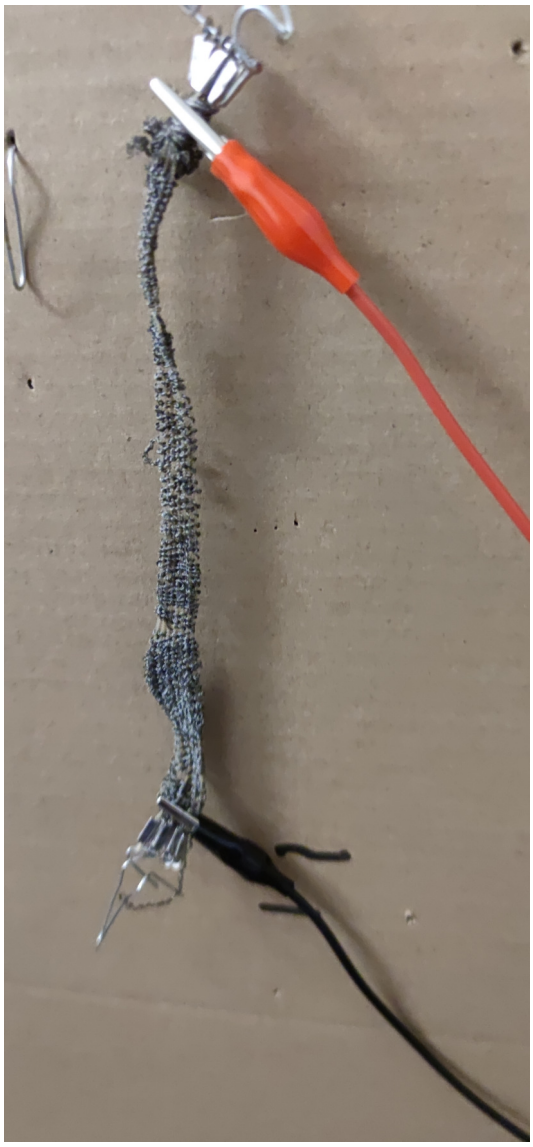


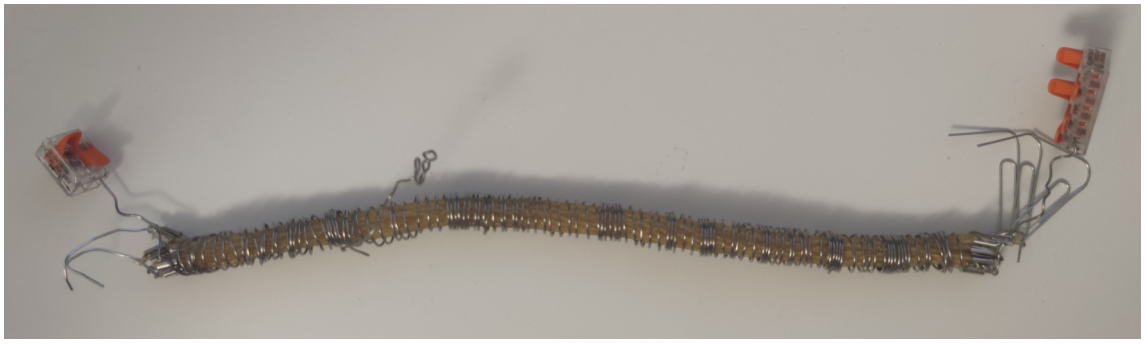
Figure 1: Artificial muscle woven with a silver coated sewing thread

Despite the fact that this approach was one of the recomended in the paper[1] It was not possible to get decent results. The resistance of the muscle was measured to be $R = 450\Omega$. Despite this fact after connecting it to power supply $U = 12V$ the current was $I = 0.00A$. Measuring the resistance again gave $R = \text{inf}$.

Hypothesis: In some less dense spot temperature reached high values and the silver coat evaporated or sewing thread burned.

2.2 Final design

Finally muscles were paired to avoid untwisting during operation. Then pairs were organized into larger muscle and put inside coiled heating wire. Heating element was Kanthal™ wire, a product used for cutting a styrofoam.



3 Temperature control

3.1 Tested approaches

3.1.1 Diode resistance

Voltage dropout on a diode depends on its temperature therefore it is possible to measure temperature by measuring voltage on a diode. However this approach had to high thermal inertia to be reliable.

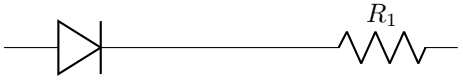


Figure 2: Diode based thermometer

3.2 Final design

Thermistors have a complex formula for their resistance. The equations were solved using matlab software.

$$\beta = \frac{T_1 T_2}{T_2 - T_1} ln\left(\frac{R_{T_1}}{R_{T_2}}\right)$$

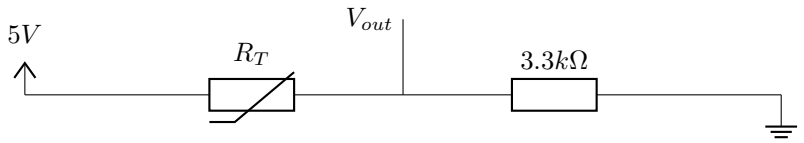


Figure 3: Thermistor based thermometer

Final characteristics presented in Figure 4 is close to linear in the task scope.

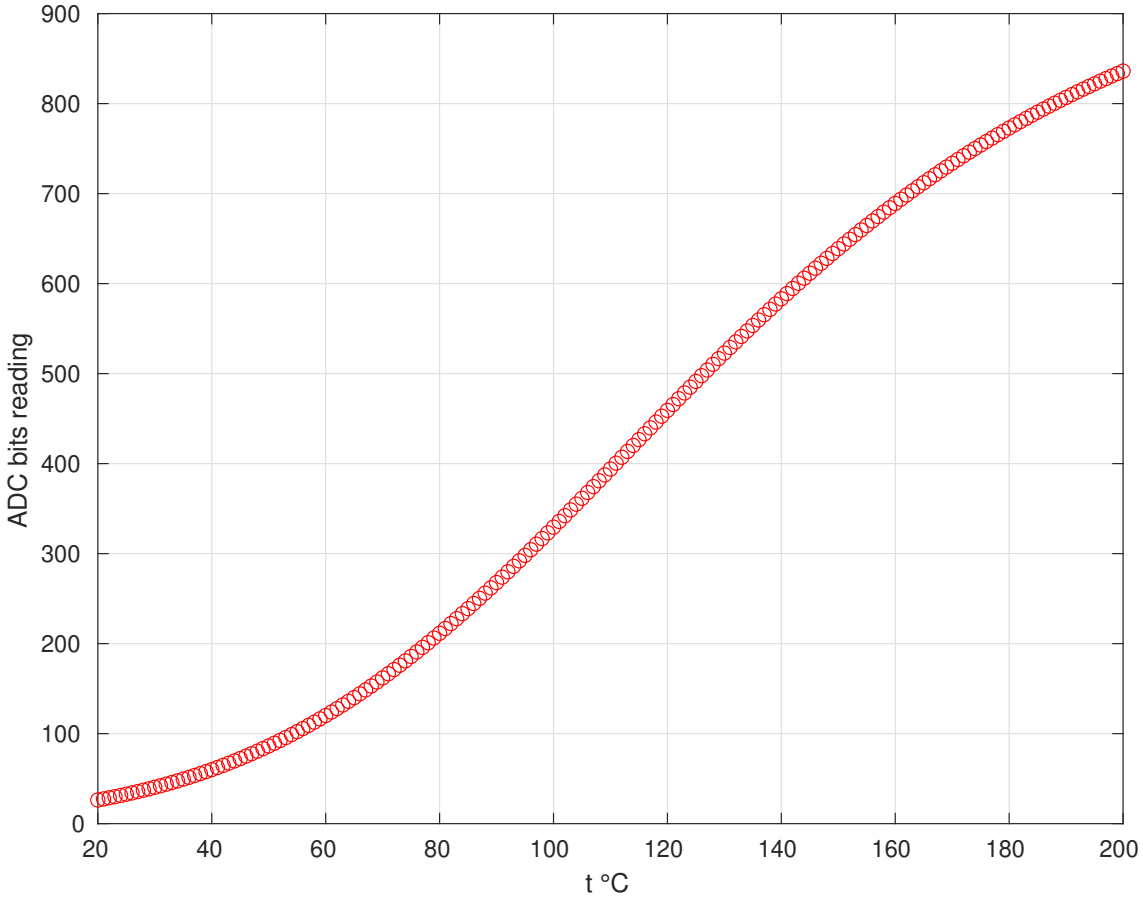


Figure 4: ADC reading to temperature

4 Results

Manipulator is controlled by arduino uno board. PID controller adjust low frequency pwm duty cycle according to temperature reading. Manipulator reaches desired position in a minute. Operating device can be seen on sped up video.

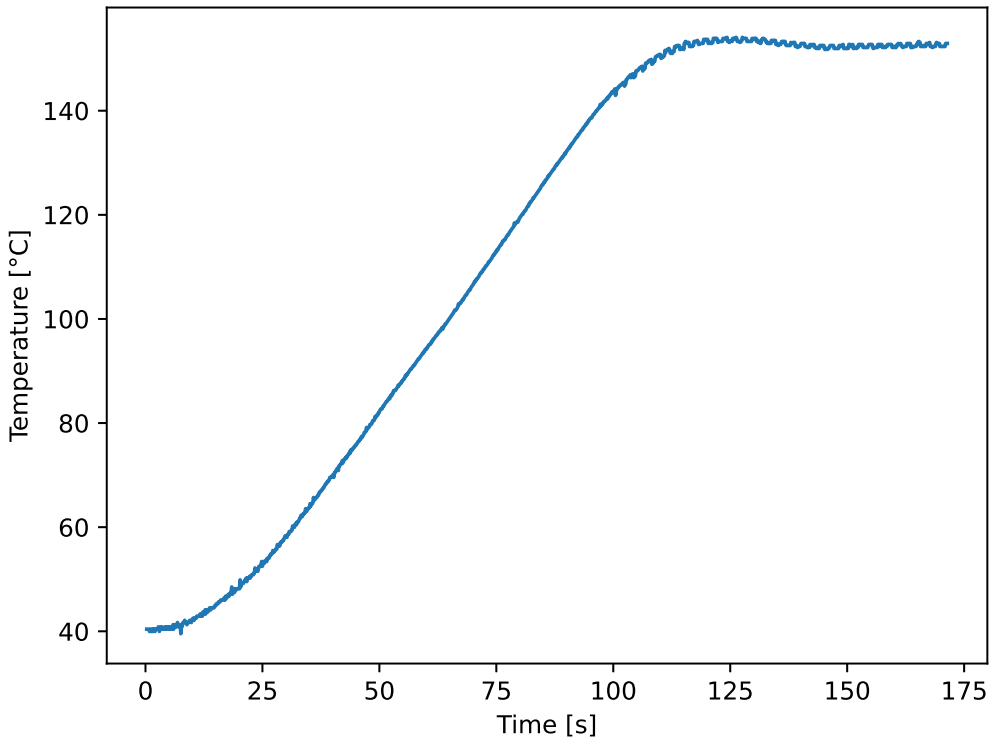


Figure 5

5 Conclusions

The project has been mostly successful. The muscle was able to lift relatively heavy link with high moment of inertia. Unfortunately the movement speed was very slow. The author believes it would be possible to obtain a better results with more evenly coiled heating wire and higher input voltage. Only one of two planned joints was operational. The second joint would require some kind of transmission as it should move further and doesn't need high torque. All things considered the project has a potential for further develepment.

References

[1] C. S. Haines, M. D. Lima, N. Li, G. M. Spinks, J. Foroughi, J. D. W. Madden, S. H. Kim, S. Fang, M. J. de Andrade, F. Göktepe, Özer Göktepe, S. M. Mirvakili, S. Naficy, X. Lepró, J. Oh, M. E. Kozlov, S. J. Kim, X. Xu, B. J. Swedlove, G. G. Wallace, and R. H. Baughman, "Artificial muscles from fishing line and sewing thread," *Science*, vol. 343, no. 6173, pp. 868–872, 2014. [Online]. Available: https://www.science.org/doi/abs/10.1126/science.1246906