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Optimizing a Passive Tracking Solar Panel System

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Abstract

Renewable energy has been gaining attention from individuals to government agencies as the negative effects of fossil fuel usage has been realized. Solar power is a reliable and green alternative to fossil fuels. Solar power is harnessed through the direct absorption of rays from the sun. In this experiment, a passive sun-tracking system using a shape memory alloy (SMA), gears, and a fresnel lens rotated a solar panel to face the sun throughout the day. At the end of the day the system rotates the solar panel back to the east in preparation for the next day's cycle to begin. This system relies on zero external electricity, making it cost effective and suitable for remote locations where electricity is not easily obtained. The rotation mechanism for the system starts with the shape memory alloy being heated by the sun, which causes it to contract, pulling the sprag gear and turning the solar panel to face the sun. In order to turn the solar panel back to the east at the end of the day, a plastic arm that has elevated toward the reset system trigger will push the trigger over allowing the gears and panel to return to their initial positions. The focus for the project this summer was to optimize the reset system, optimize the Fresnel lens placement, and complete testing.

Introduction

Benefits of solar energy

- Inexhaustible
- Available in most parts of the world
- Virtually no pollution

Figure 1.

The benefits of the OBU Prototype

- Increased sunlight absorption
  - Follows the azimuth angle of the sun
- Passive tracking of the sun through the use of a Shape Memory Alloy (SMA)
  - Requires no external electricity or programming to face the solar panel towards the sun
  - The austenite phase is rigid and programmable.
  - The martensite phase is elastic.
- Season adjusting capabilities
  - The seasonal axis is adjusted manually

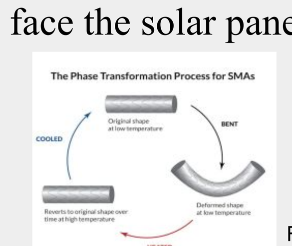

Figure 2.

General Design and Function

1. Each hour the Fresnel lens focuses sunlight onto the SMA, thus heating it.
2. The SMA contracts, rotates the gears, and turns the panel and lens 15° toward the west.
3. As the lens moves out of the direct angle of the sun, the SMA cools below the transition temperature and is lengthened by the weight on the pulley system.
4. The sun tracks across the sky 15° every hour, initiating eight cycles of heating and cooling of the SMA.
5. Throughout the day a release system is "charged" by each cycle of gear rotation. At the end of the day, the reset system is initiated by a weighted trigger falling onto a release pawl. This turns the solar panel back to the east in preparation for the next day's cycle.

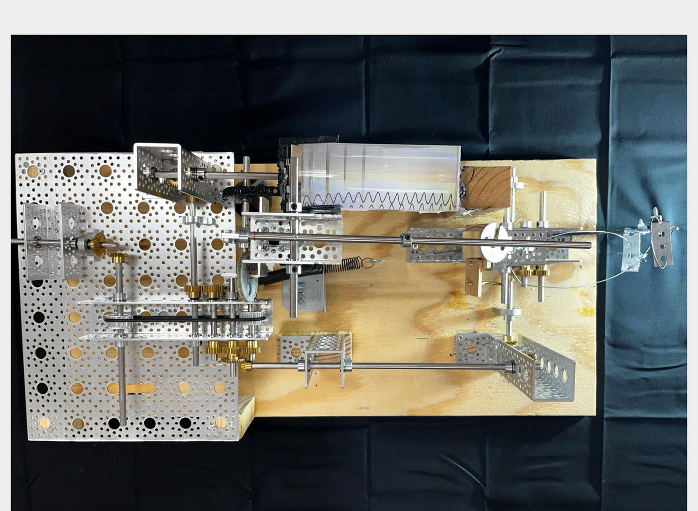

Figure 3. Top view of rotor system

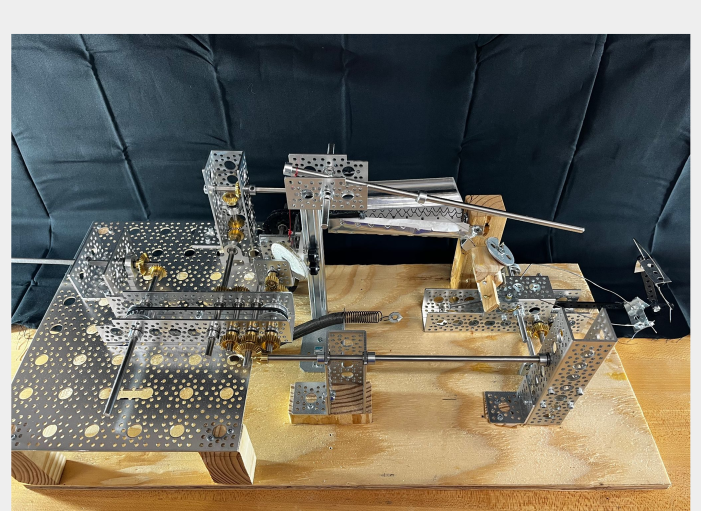

Figure 4. Side view of rotor system (housing not included)

Delayed Trigger Reset System

Primary functions:

- Rotate the solar panel back to the east at the end of the day
- Disengage the sprag gear axle

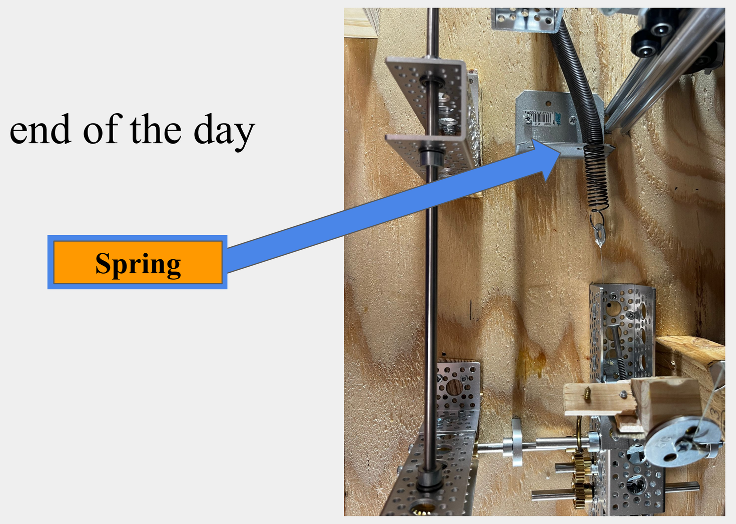

Figure 5.

Components of reset system

Incremental energy storage

- *Spring*
- *Gear*
- *Pawl*

With each rotation of gears as the SMA contracted, energy was built up in the spring. The gear was withheld from spinning back with a pawl that only allowed the gear to rotate one direction when in contact with the gear.

Energy release

- *Hammer trigger*
- *Arm of reset*
- *Aluminum rod*

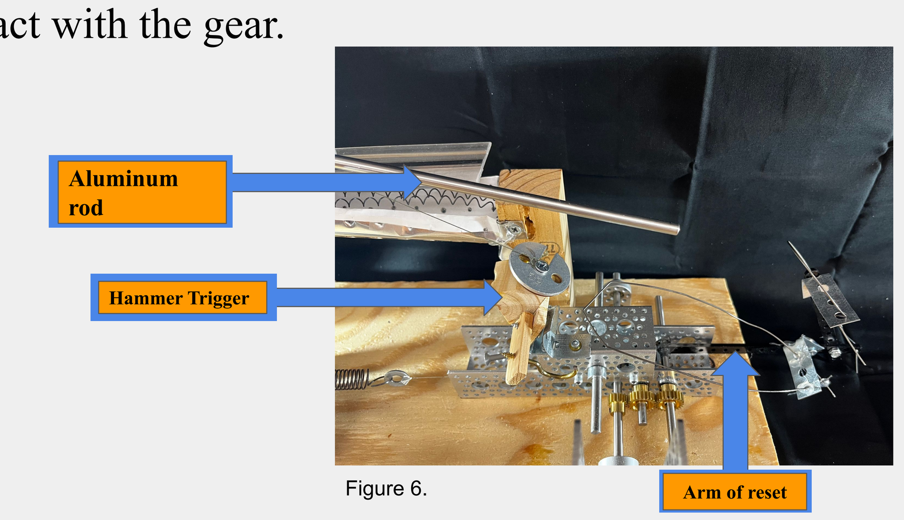

Figure 6.

The arm of reset was lifted throughout the day towards the hammer trigger with each rotation of the gears as the SMA contracted. At the end of the day the arm of reset pushed the hammer trigger over onto a nail that lifted the pawl. As the pawl lifted a string attached to a rod disengaged the sprag gear axle from the system, allowing the spring to contract turning the solar panel back to the east.

Catch and Reset

- *Catch system*

In order to reset the hammer trigger, the catch system was created. Attached to the arm of reset is a wire that engaged with a hook to pull the hammer trigger back into its leverage position as the arm of reset fell. Once the hammer trigger was back into the leverage position, the wire disengaged with the hook and the system was ready for the next day.

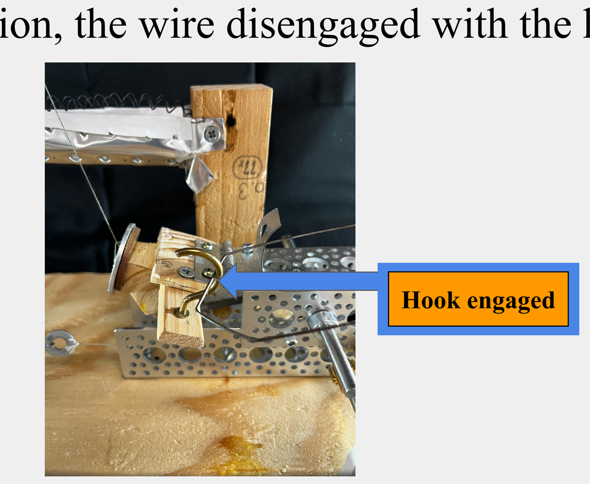

Figure 7.

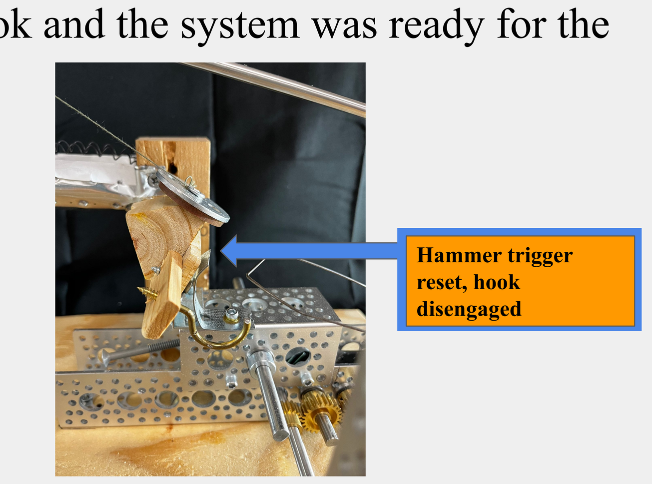

Figure 8.

References

1.J.M.K.C. Donev et al. (2020). Energy Education - Radiant heat [Online]. Available: https://energyeducation.ca/encyclopedia/Radiant_heat. [Accessed: July 21, 2021].

2. Poulek, Vladislav. (1994). New low cost solar tracker. Solar Energy Materials and Solar Cells. 33. 287–291. 10.1016/0927-0248(94)90231-3.

3. V. Poulek, "Testing the new solar tracker with shape memory alloy actors," Proceedings of 1994 IEEE 1st World Conference on Photovoltaic Energy Conversion - WCPEC (A Joint Conference of PVSC, PVSEC and PSEC), 1994, pp. 1131-1133 vol.1, doi: 10.1109/WCPEC.1994.520161.

Acknowledgements

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SMA Strength Experiments

Experiments were performed to test the strength of the SMA spring because the added weight to the reset system alluded to the requirement of a stronger pulling force from the SMA.

Testing the strength of one SMA

This experiment was conducted using a blow dryer with an attachment to spread hot air out, a pulley that the weight was attached to, and a box to hold the SMA, seen in Figure 9. The SMA was heated with the blow dryer until it had pulled the weight attached 14 ± 1 cm. The time it took to pull the weight was recorded and is shown in Figure 10.

Testing the strength of one SMA versus two

This experiment was conducted using a blow dryer with an attachment to spread hot air across the entire SMA, a box to hold the SMA, and a pulling force meter, seen in Figure 11. The SMA was attached to a stationary box on one end and a pulling force meter on the other. The SMA was heated until maximum contraction had occurred, and the reading on the force meter was recorded. This was conducted with one SMA, and then two that were intertwined.

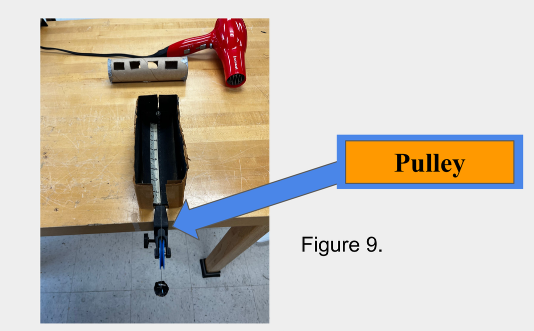

Figure 9.

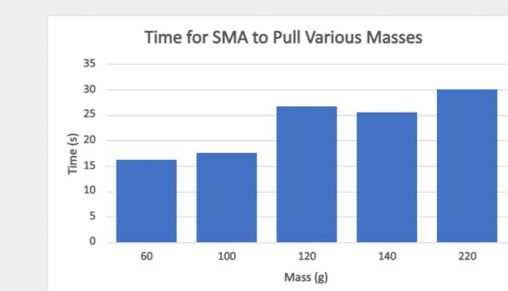

Figure 10.

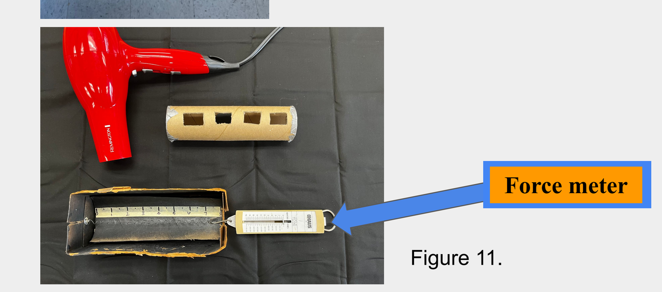

Figure 11.

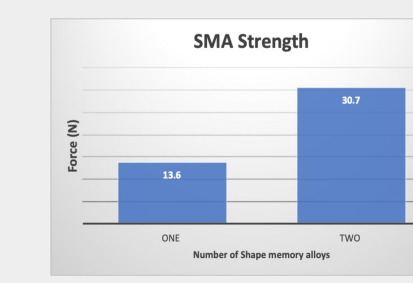

Figure 12.

Fresnel Lens Alignment

The Fresnel lens was used to heat the SMA spring above its transition temperature and cause it to contract by focusing sunlight onto the spring. Proper alignment of the Fresnel lens is essential.

Improvements include:

- *Upgraded mount (Figure 13) to hold more accurate rotation*
- *Stability of the lens for maximum energy absorption*
- *Proper alignment*

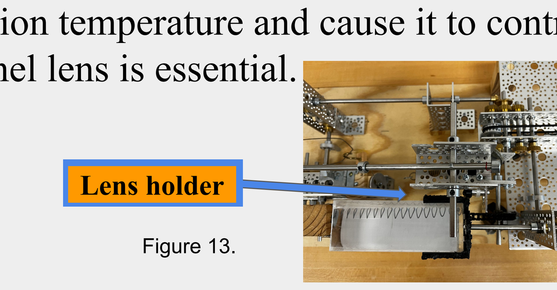

Figure 13.

Attaching Solar Panel

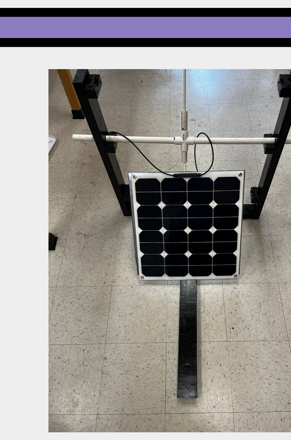

Figure 14.

Solar panels gain the most energy when faced perpendicular to the sun's rays. To achieve this the solar panel must:

- rotate East to West throughout the day as the sun does.
- have an adjustable vertical angle to account for the varying height of the sun in the sky during different seasons.

A jointed attachment off the gear system was added. This allows the support rod and panel to be oriented at different vertical angles as well as move East to West while minimizing friction in the gears.

Additional Energy Source

Small solar panels from garden stake lights (Figure 15) were explored as an option for an additional power source. Each battery holds 1.2-1.5V of energy, and by connecting these in series, a higher overall voltage is achieved. Attaching small stake lights in series could give additional power, if needed.

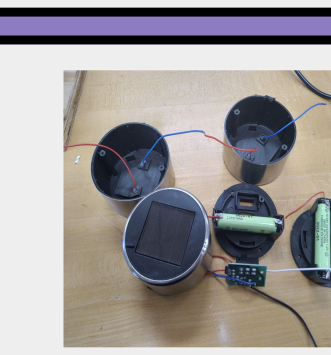

Figure 15.

Future Work

- Investigate ways to attach more than one solar panel to the current model.
- Investigate ways to expand the system to a larger scale.
- Optimize the wood stand to make the seasonal adjustment non-manual.
- Incorporate alternative forms of green energy production (i.e solar windows in the box holding the system or wind turbines underneath the wood stand) and compare the energy absorption.
- Further investigate how sending an electrical current through the SMA(s) for contraction could be done safely through the use of solar stake lights or an alternative form of green energy.