SMA BASED AUTONOMOUS ROBOTIC ACTUATION FOR DEPLOYABLE LIGHT SOLAR SAIL PROTOTYPE

ABSTRACT

This paper is about SMA based small light Solar Sail. The main task is to open and close the Solar Sail in the Space. Here the Origami Robotics approach has been obtained to synchronize the Solar Sail. This kind of Compliant Robotics approach for Solar Sail Actuation could save space before deployment of Aerospace application.

OBJECTIVE

- Shape Memory Alloy Actuators are a particular group of metallic materials exhibiting unique properties, mainly superelastic and shape memory effect.
- **Origami Robotics** is an area of Robotics to deal with foldable robotic function.
- **Shape memory effect** is the ability to recover the original shape from a deformed upon heating above austenite finish temperature.
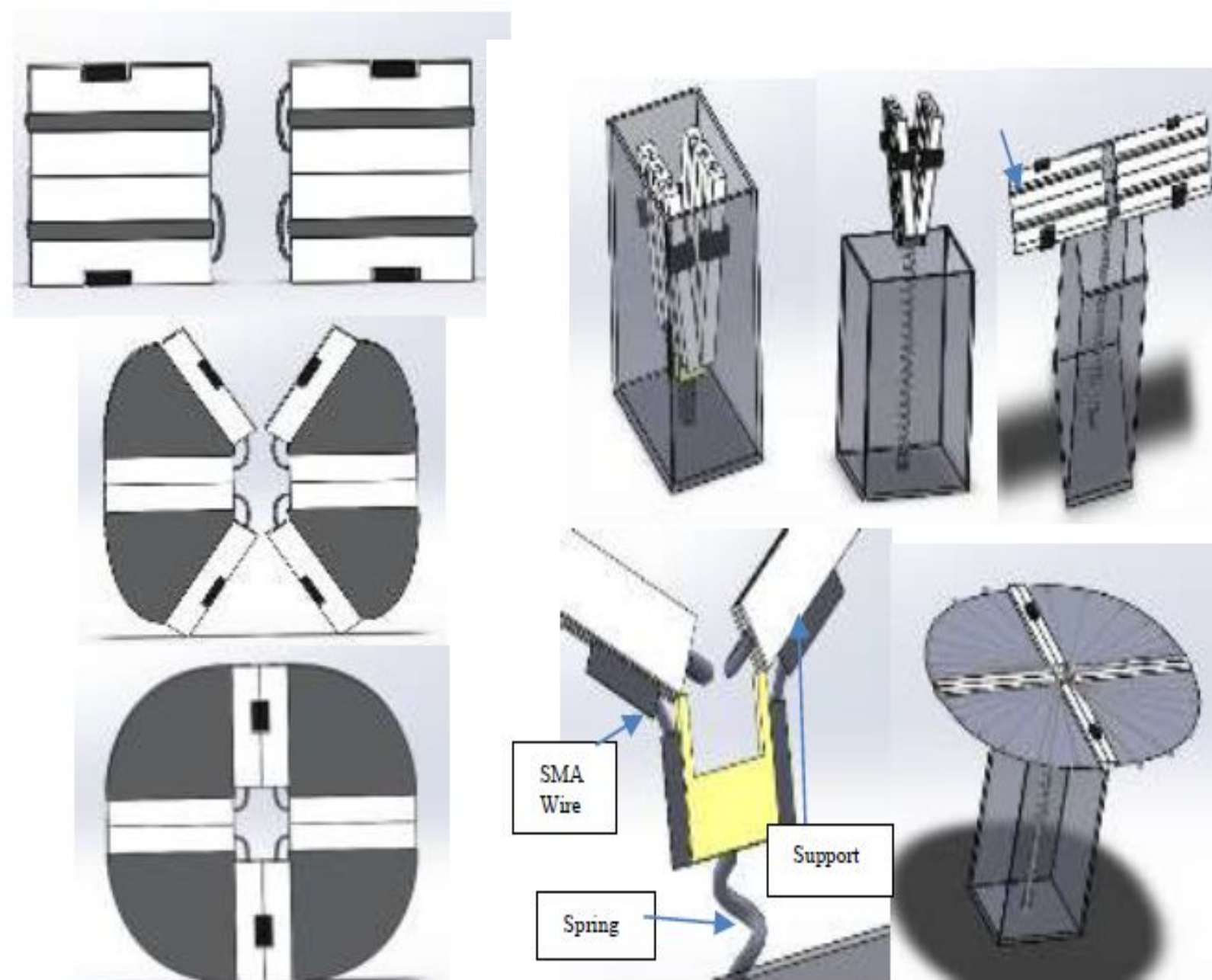
CALCULATION

Calculations for SMA actuation,

$$\text{Input energy} = E_{elec} = I^2 R_{tot} \, dt$$
$$R_{tot} = \rho_{Rtotal} L_o / A$$
$$\rho_{Rtot} = [\rho_{Rm} \xi_m + \rho_{Ra} (1 - \xi_m)]$$
$$E_{heat} = \rho_o V_c dT_m + \rho_o V \Delta H \mid d\xi_m \mid$$
$$E_{mech} = F_{act} \Delta x = F_{act} L_o \varepsilon_{tot}$$
$$E_{elec} = E_{heat} + E_{mech} + E_{loss}$$

Neglecting the E_{loss},

$$E_{mech} = F_{act} \Delta x = E_{elec} - E_{heat}$$

where
t - Time (s)
I - Input current (A)
R_{tot} - Resistance (ohm)
L_o - Initial Length (m)
ρ_{Rtot} - Total resistivity (ohm.m)
V - Volume (m^3)
A - Cross sectional area (m^2)
ρ_o - Density (kg/m^3)
ρ_{Rm} - Martensite Resistivity (ohm)
ε_{tot} - Strain
ρ_{Ra} - Austenite Resistivity (ohm)
ξ_m - Martensite Volume fraction (from Hysteresis graph)
C - Specific Heat capacity (J/kgK)
ΔH - Latent Heat (J/kg)
F_{act} - Actuating Force (N)

RESULT

The whole Solar Sail mechanism can shrink to 17.75 % of the original size.

Fig 5: Closed (around 0 degree) and Opened position (90 degree) of the Light Solar Sail Prototype

Fig 1: Stages of Deployment
Fig 2: Flexible Robotic approach for the deployment of Solar Sail
Fig 3 : Analysis of Single Section
Fig 4: Fully Opened position of Solar Sail
Fig: 3
Fig: 4
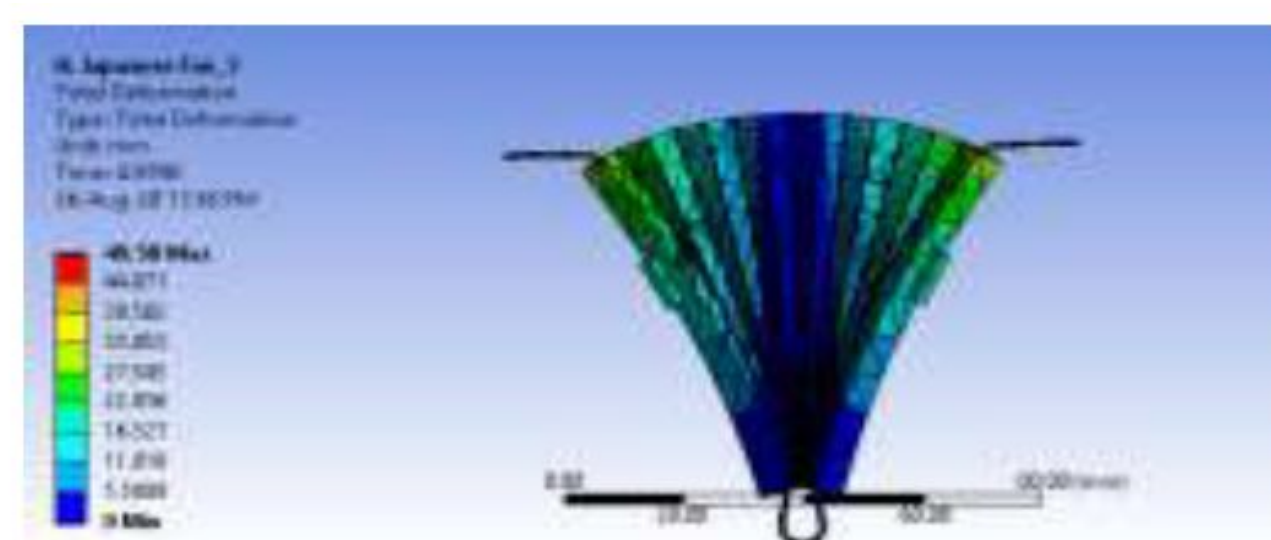
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