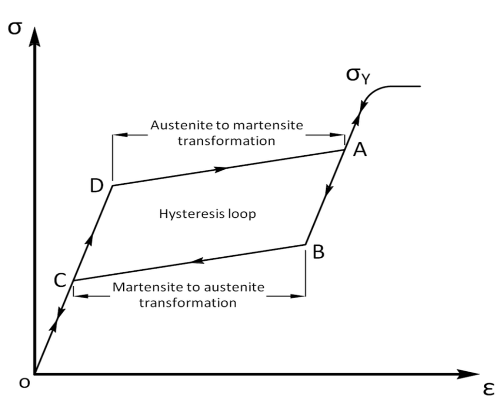
# ANSYS Simulation for Shape Memory Alloy Wire Actuator

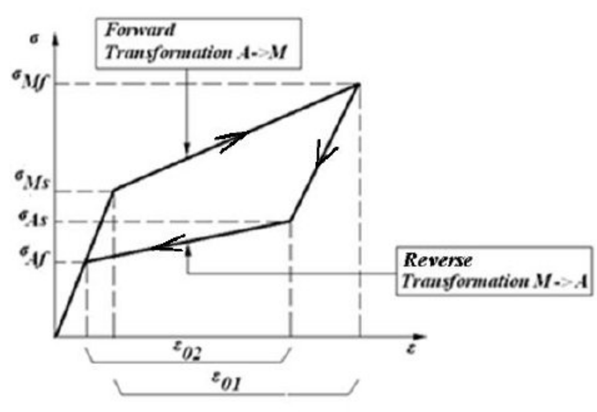
1. Introduction

Shape memory alloys (SMA) are smart materials having distinctive behavior such as shape memory effect and pseudoelasticity. A reversible solid-state displacive phase transformation from austenite to martensite is the reason behind the smart behavior. SMAs are metallic alloys and categorized as NiTi-based alloys (NiTi, NiTi Cu), copper-based alloys (CuZnAl, CuAlNi), and iron-based alloys (FeNiCoTi, FeMnSi). The SMAs exhibit high actuation energy densities and have the capabilities to recover their shape under large applied loads. SMAs can exist in two phases having three different crystal structures viz. twinned martensite, detwinned martensite, and austenite. The martensite is a low-temperature phase while the austenite is stable at high temperatures. The phase transformations have characteristic start and finish temperatures and give information about the operating range of an alloy. Ms, Mf, As, and Af are the characteristic temperatures of the martensite and austenite transformations.

Nickel-Titanium or Nitinol alloys are widely used SMA due to their exhibition of excellent mechanical properties, thermomechanical behavior, pseudoelasticity, and biocompatibility. They have the highest work density and large deformation recovery among other SMA compositions. It is the most studied SMA alloy system and has been applied in a variety of commercial applications. In addition to mechanical properties, the transformation temperatures are one of the most important characteristics which decide the applicability of the SMA.

The Figures below highlight the Shape Memory effect and the Pseudoelecticity effect in NiTi.



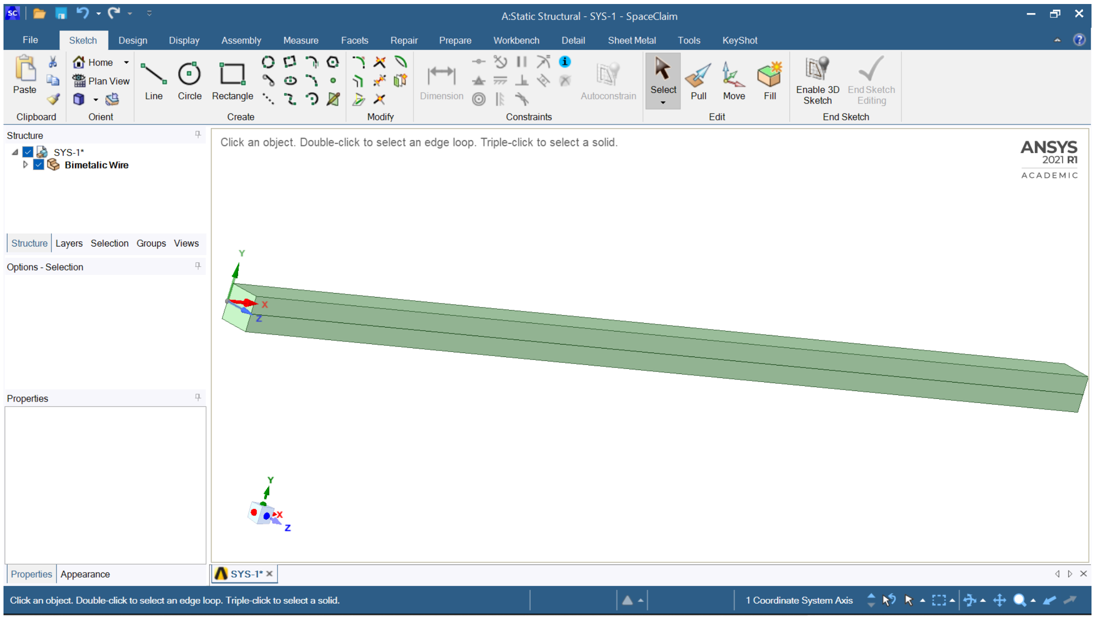
2. Engineering Data

Density, Isotropic Elasticity & Shape Memory effect Parameters were applied in the software from the relevant literature.

| | |
|---|---|
| Density | 6450 kg $m^{-3}$ |
| Isotropic Elasticity | |
| Young's Modulus | 51700 MPa |
| Poisson's Ratio | 0.33 |
| Bulk Modulus | 43083 MPa |
| Shear Modulus | 19884 MPa |
| Shape Memory Effect | |
| Hardening Parameter | 1000 MPa |
| Reference Temperature | 22 C |
| Elastic limit | 140 MPa |
| Temperature Scaling Paramtere | 5.6 MPa $C^{-1}$ |
| Maximum transformation strain | 0.1 mm $mm^{-1}$ |
| Martensite Modulus | 51700 MPa |
| Load Dependency parameter | 0 |

3. Geometry

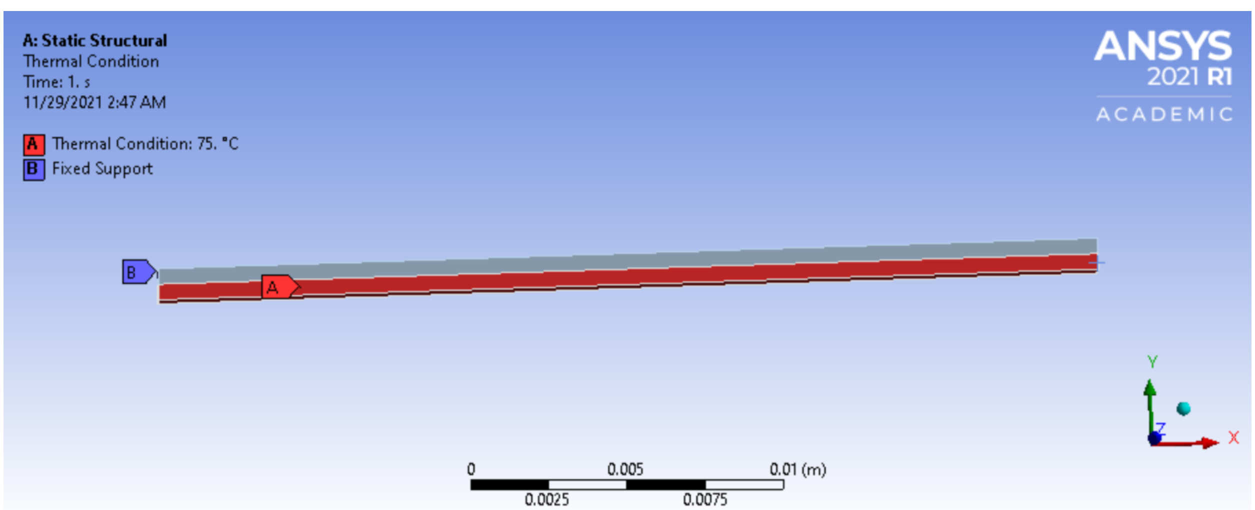
The geometry is modeled as a bimetallic wire with a cuboidal structure. The lower wire is made of NiTi material with properties as specified above in the engineering data, while the upper body is made of standard structural steel.




4. Analysis

Boundary Conditions: A fixed support to one end of the bimetallic wire

Initial Conditions: Thermal Condition of 75 degrees Celcius (Austenite Start Temperature)

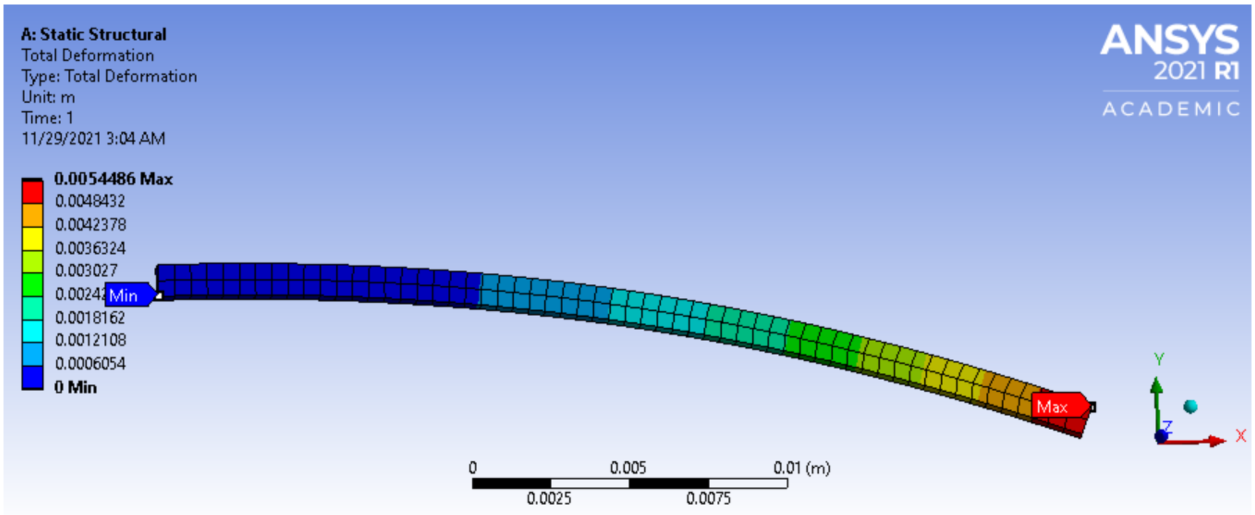



The analysis is performed to determine the total deformation

5. Results

Bending deformation was produced due to the thermal condition corresponding to the Austenite start temperature of NiTi alloy wire. The simulation returned valid convergent results up to 95 degrees Celcius, Austenite finish temperature.

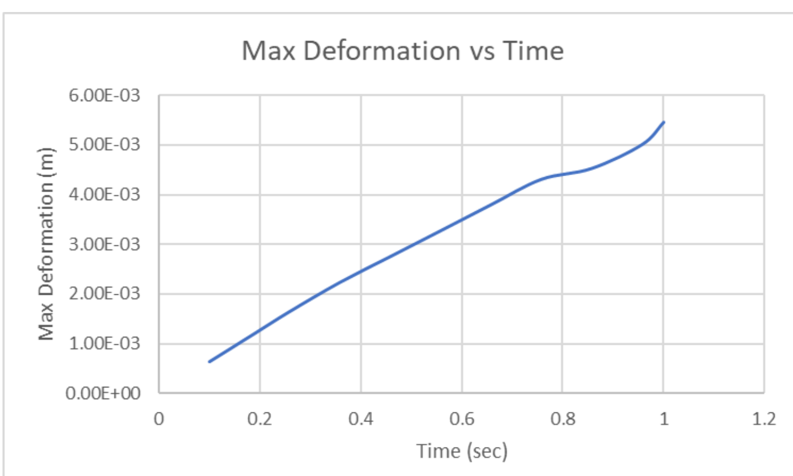
The Max deformation in the wire: 0.544 cm



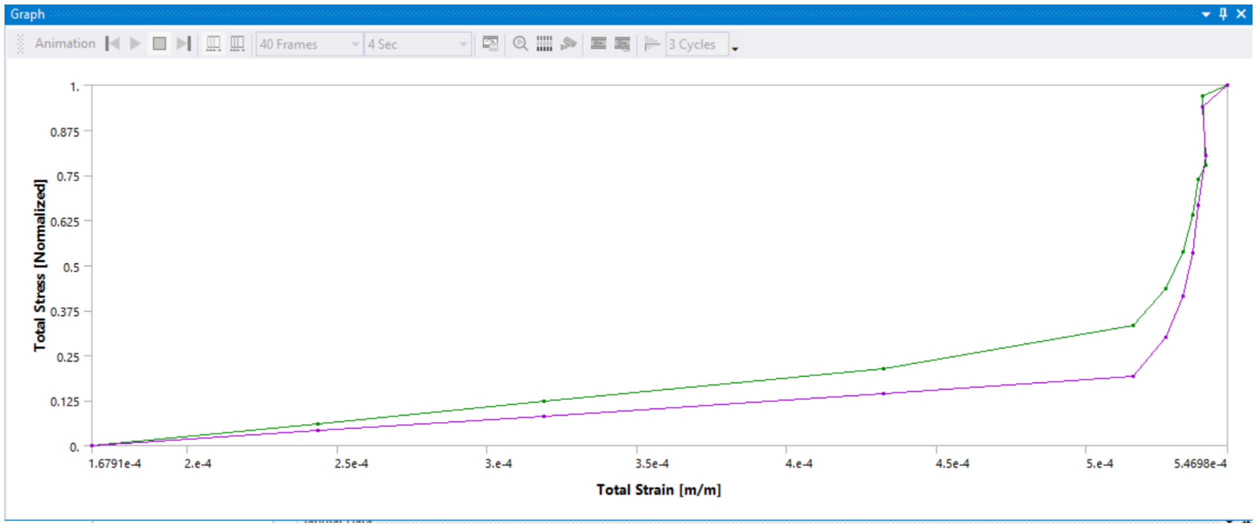

6. Post Processing

We obtain the following plots:

i) Deformation vs Time



ii) Stress vs Strain (hysteresis)




7. Results and Discussions

An SMA wire actuator has been developed and its thermomechanical behavior has been investigated. The actuation characteristics with respect to temperature have been investigated. A maximum surface temperature of 75 degrees celsius has been found through simulation. Through thermal (joule heating) actuation, the developed actuator shows a max displacement of 0.544 cm and is validated through the hysteresis curve obtained from post-processing.