

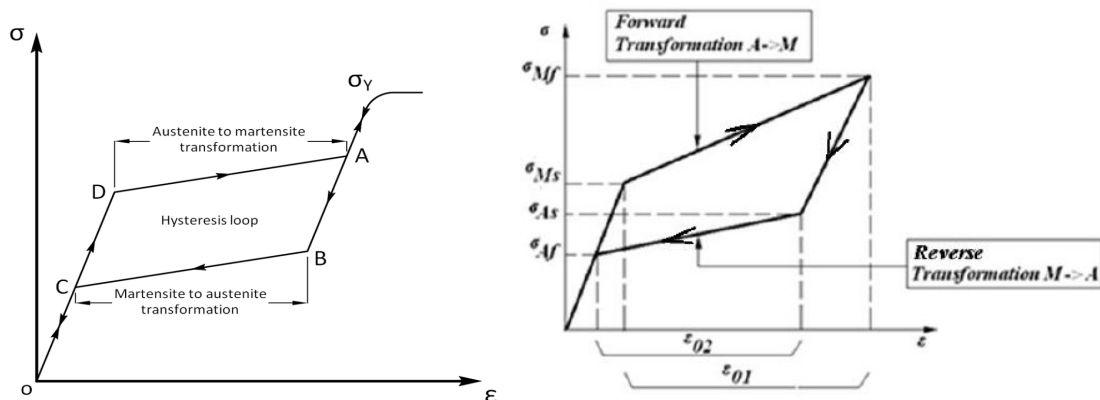
# ANSYS Simulation for Shape Memory Alloy Spring Actuator

## 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.  $M_s$ ,  $M_f$ ,  $A_s$ , and  $A_f$  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 Pseudoelasticity effect in NiTi.



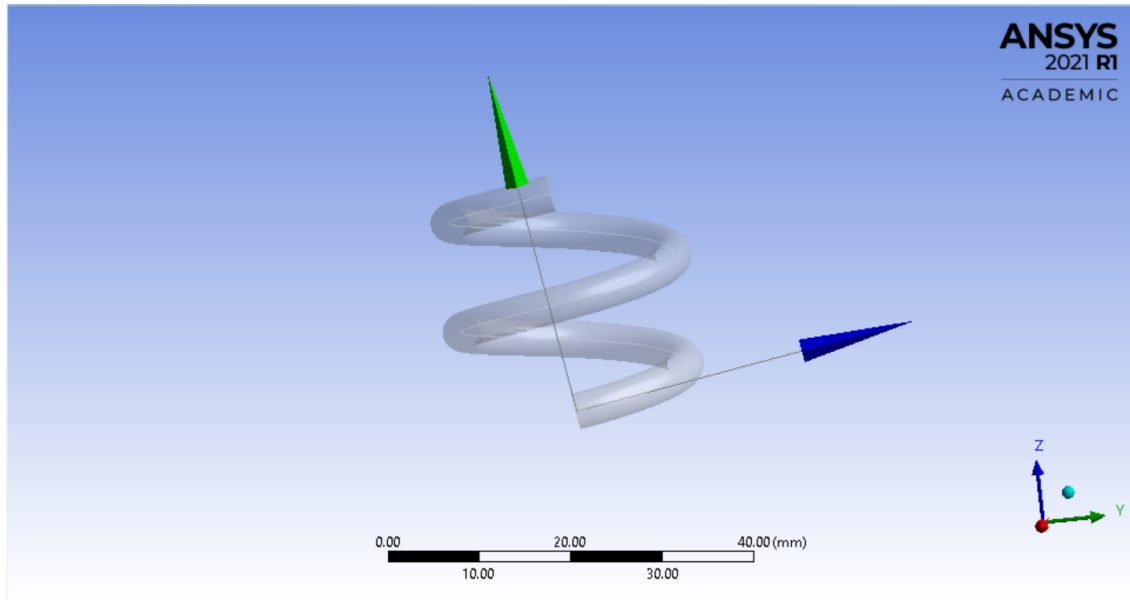
## 2. Engineering Data

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

|                               |                         |
|-------------------------------|-------------------------|
| Density                       | 6450 kg m <sup>-3</sup> |
| 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 <sup>-1</sup> |
| Maximum transformation strain | 0.1 mm mm <sup>-1</sup> |
| Martensite Modulus            | 51700 MPa               |
| Load Dependency parameter     | 0                       |

## 3. Geometry

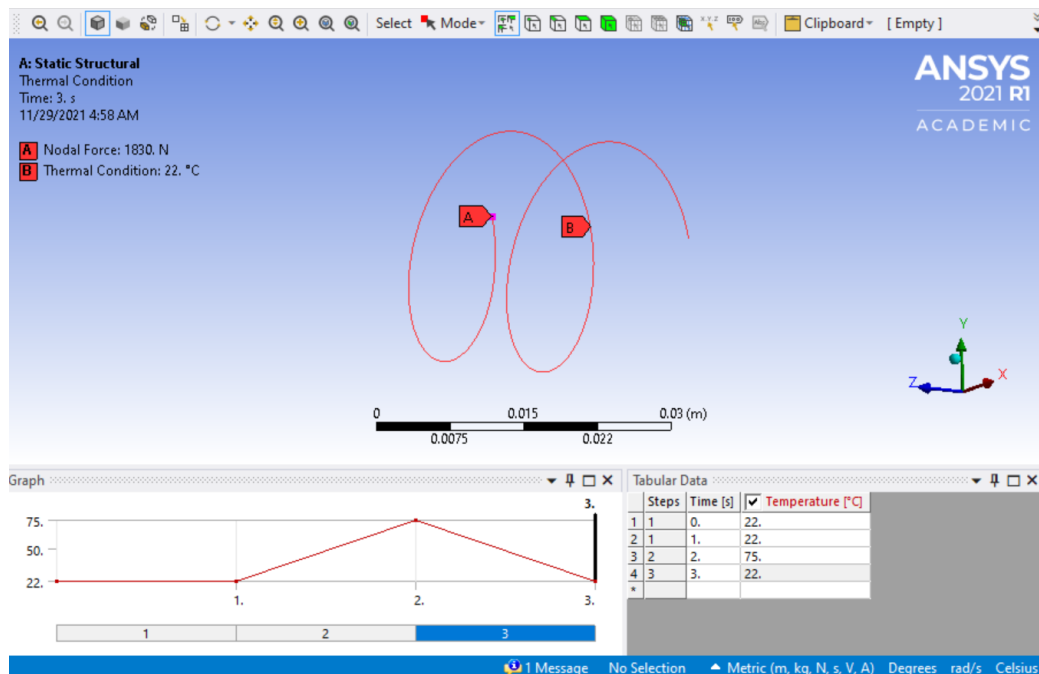
The geometry of spring is modeled with a diameter of 10mm via a sweeping command in the ANSYS Design modeler, the design is assigned the NiTinol material.



#### 4. Analysis

Initial Conditions: Thermal Condition of step tabular size degrees Celcius (from 22 to 75 Cecluis in 3 steps )

Nodal force: 1830 N For de-twinning the spring



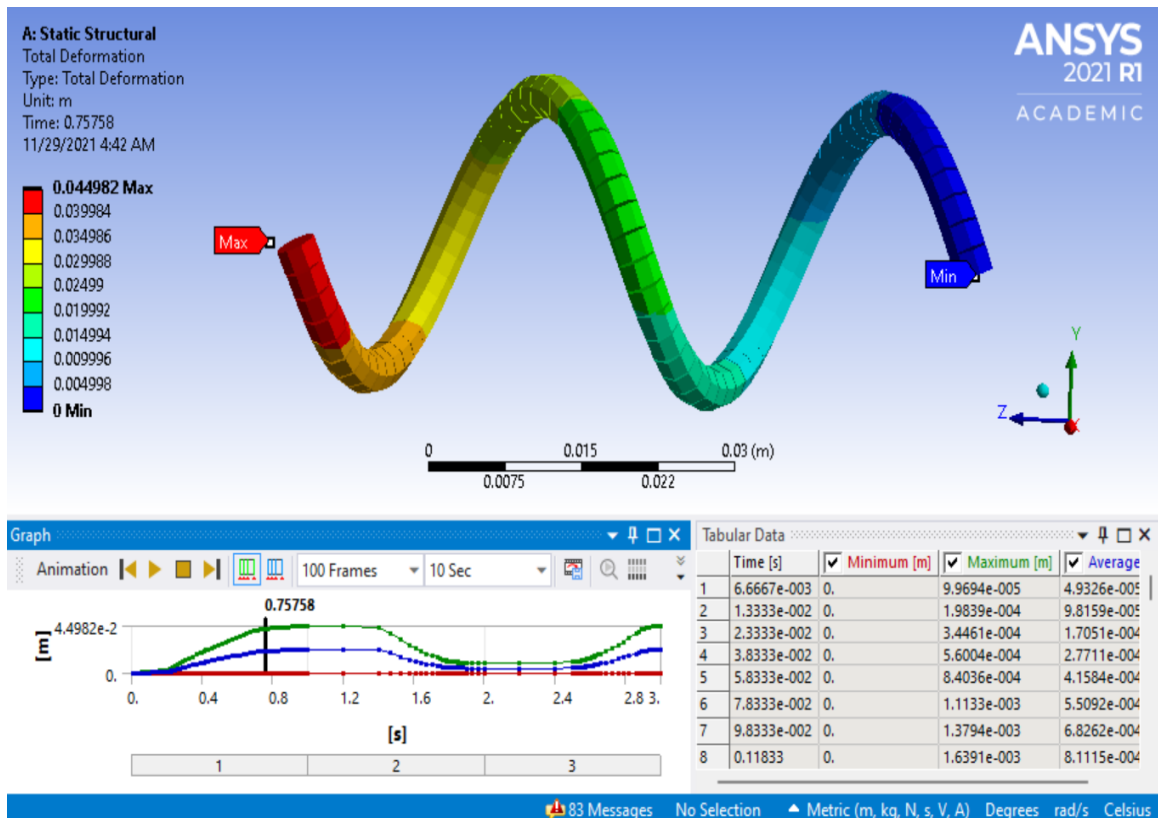
The analysis is performed to determine the total deformation

## 5. Results

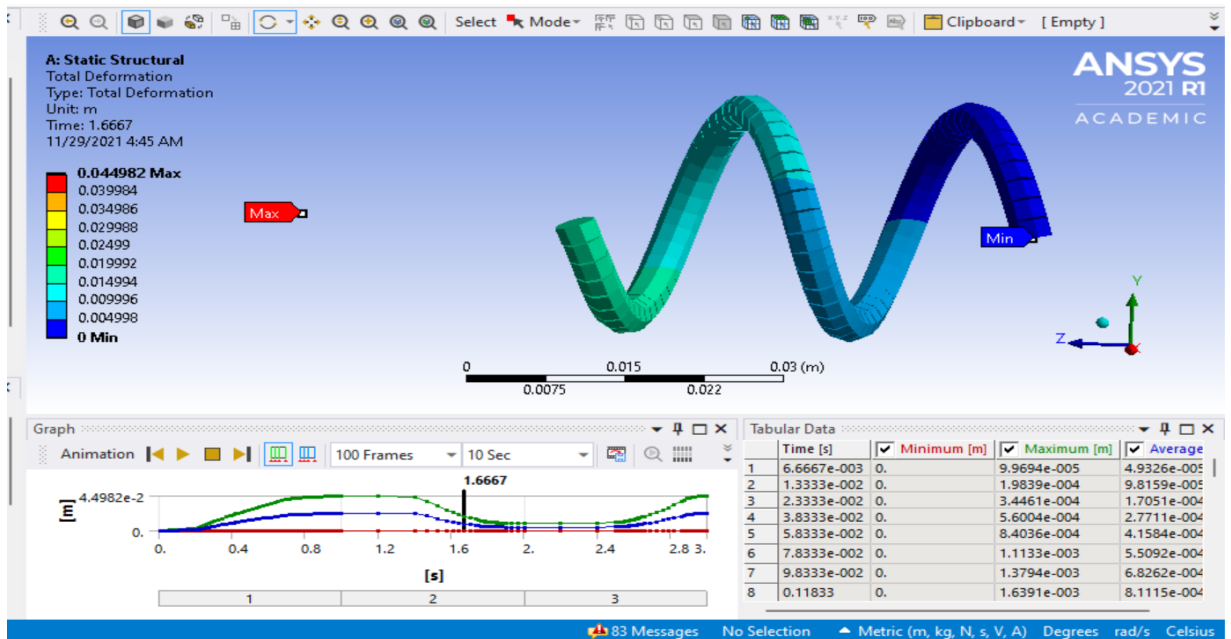
Spring activates initially due to the de-twinning of the structure because of the applied nodal force. After the activation, the spring contracts and produces actuation as the temperature reaches austenite start ( $A_s$ ) for NiTiNol spring.

The Max deformation in the spring: 4.49 cm

Initial activation due to de-twinning:

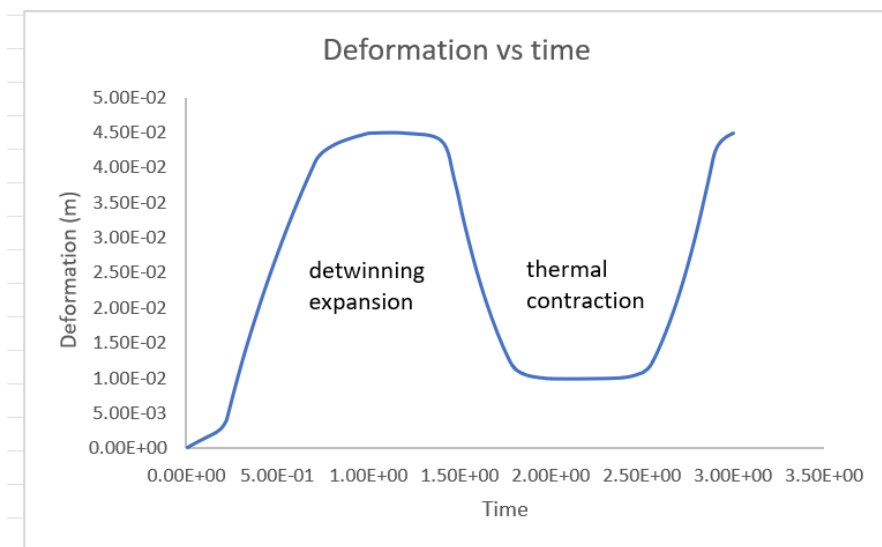


Actuation (contraction) due to thermal activation:



## 6. Post Processing

We obtain the following plot:



The plot obtained shows two phases of the actuation namely: Detwinning expansion and thermal contraction (actuation) at austenite start temperature.

## 7. Results and Discussions

An SMA spring 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 4.49 cm