Performance Evaluation of SMA NiTi Helical Spring at Various Temperatures

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Abstract: **Shape memory alloys (SMAs) are one of the most widely used smart materials in many applications because of their shape memory effect property and pseudo elastic behavior. In this work, the behavior of NiTi SMA helical spring was evaluated at various temperatures. The unique property of SMAs temperature dependent Young's modulus has been used to change the stiffness of the spring. The experiments were carried out at different temperatures to determine the stiffness of SMA spring. The experimental results shows that SMA based helical springs stiffness increases with increase in temperature and deflection decreases with increase in temperature. The result demonstrates SMA springs have great potential and can be used to control the vibrations.**

Keywords -NiTi, Shape Memory Alloy (SMA) Springs, Stiffness.

I. INTRODUCTION

Shape memory materials exhibit the ability to induce large mechanical strains upon heating and cooling. Many shape memory materials are metal alloys; therefore, they can also produce large mechanical stress when thermally activated. These properties make them well suited for applications in controllable shape change, vibration control, and active and semi active damping. Other types of shape memory materials are also being studied, including shape memory polymers and magnetically activated shape memory materials.

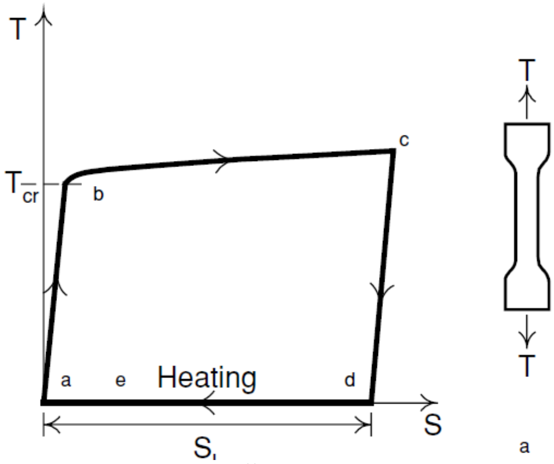

Fig. 1 Shape memory effect in shape memory materials.

The stress–strain behavior of shape memory materials exhibits two interesting nonlinear phenomena, the shape memory and pseudo elastic effects. The shape memory effect is a property by which very large mechanical strains can be recovered by heating the material above a critical temperature. This strain recovery property produces large contractions in the shape memory materials and enables their use as thermo mechanical actuators. The second property, the pseudo elastic effect, is a property by which the material exhibits a very large strain upon loading that is recovered fully when the material is unloaded. A shape memory material exhibiting the pseudo elastic effect exhibits a very large hysteresis loop in the stress–strain curve.

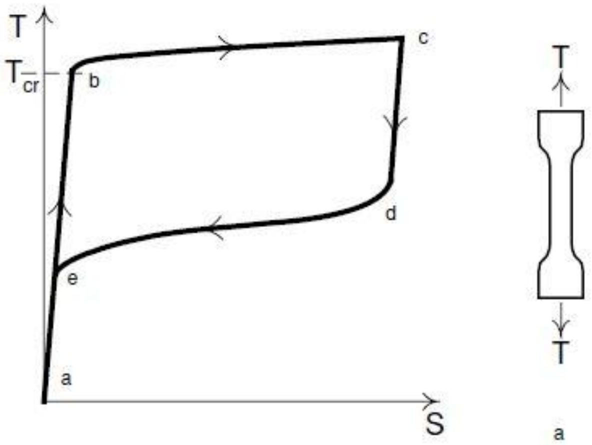

Fig..2 Pseudoelastic effect in shape memory materials.

The shape memory and pseudo elastic behavior of shape memory materials can be visualized by considering a material that is under uni-axial loading. Loading the material from a zero stress–strain state produces a linear elastic response up to a critical stress, denoted Tcr in Fig. 1. Increasing the load beyond this critical stress produces very large, apparently plastic, strain in the material accompanied by a slight increase in the load. Physically, it would seem that the material is very soft during this portion of the stress–strain curve. Unloading the material would produce a linear elastic response that would result in a residual strain SL. So far in the discussion there would be nothing to distinguish the shape memory material from any material that has been loaded to the point of plastic deformation. The defining characteristic of a shape memory material is that the residual strain can be fully recovered by heating the material beyond a critical temperature. As shown in Fig.1., heating the material produces a recovery in the strain and returns the material to the zero stress–strain state. Points a through e represent the critical transitions in the stress–strain behavior of the shape memory material.

II. EXPERIMENTAL SET UP

To analyze the performance of SMA spring, the experimental setup consists of a cantilever beam fixed with C Clamp is prepared as shown in fig.4. The SMA spring with mass was attached to the beam. The non contact type sensor is mounted above the spring to measure the deflection. Also a non contact laser temperature sensor was used to find out variation in temperature for the applied current. The spring was actuated by supplying current through multi voltage D.C. Power supply. The experimental set up was interface with computer along with PAK software. The deflection and temperature reading were noted at 0 to 3 Amps. Fig. 5 shows the temperature variation of SMA spring for the applied current.

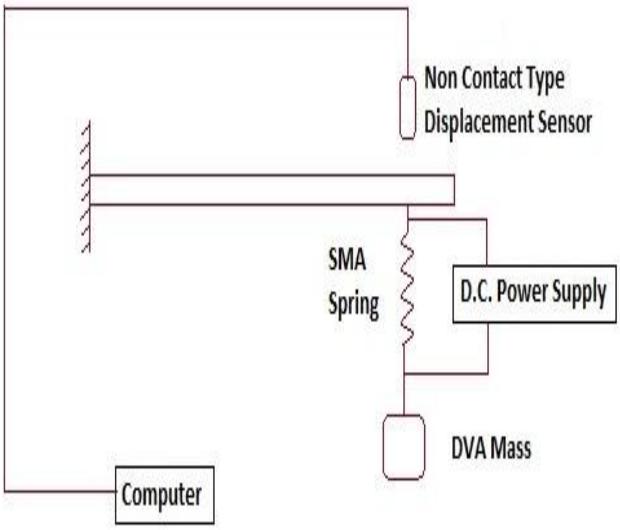

Fig. 3. Block Diagram of Experimental Set Up

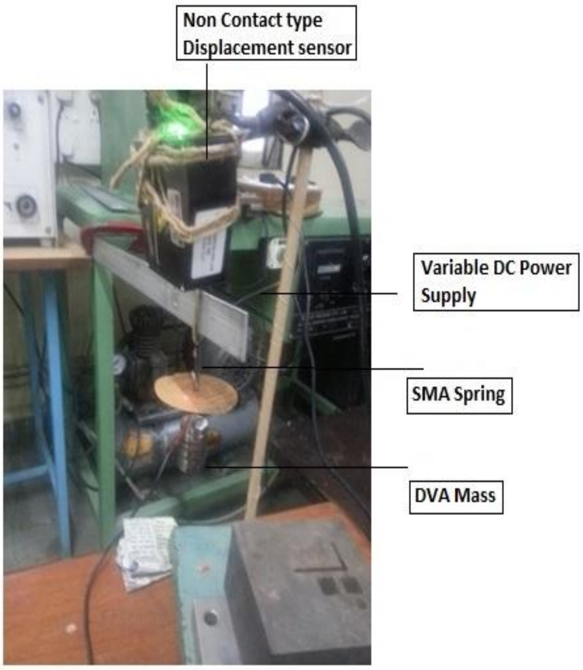

Fig. 4. Experimental Set Up

SMA is the smart material and their physical properties vary as a function of temperature. SMA springs used in this experiment were procured from Dynalloy Inc, USA. The stiffness of the spring is calculated by varying the electric current from 0 to 3 amps through variable D.C. power supply. The deflection is measured with non contact type sensor which is interfaced with computer along with PAK software. Also the temperature corresponding to supply current is measured by using non contact type laser instrument. The fig 5 & 6 shows the temperature and deflection for applied current.

III. CONCLUSION

The behavior of NiTi SMA helical spring was evaluated through experimentation. A closely coils helical spring is used for conducting experiments. It is noticed that SMA spring can generate large force and stroke for smaller dimensions. The result from experiment shows that the force increases with increase in temperature and deflection decreases with increase in temperature. Also the stiffness of spring at austenite state is around 2.57 times the stiffness of spring at martensite state.

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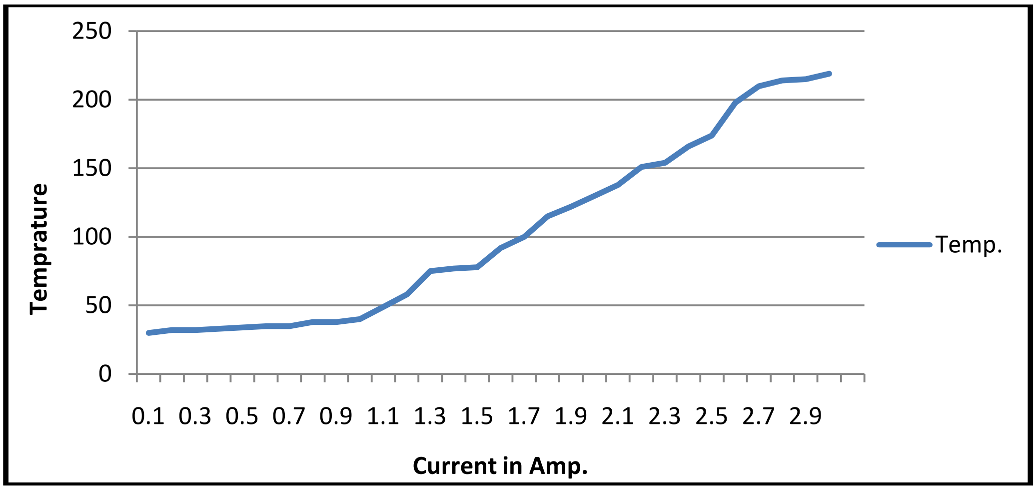

Fig 5. Graph of Current vs. Temperature

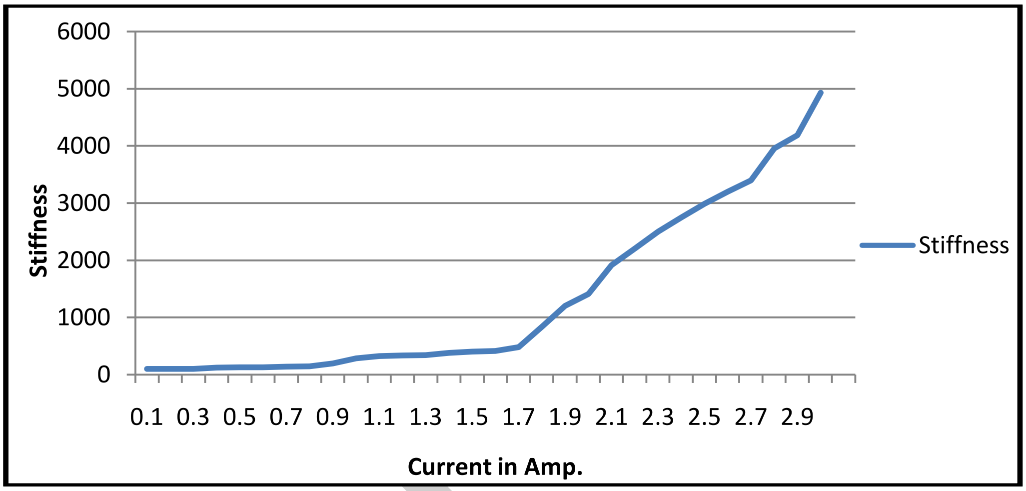

Fig 6. Graph of Current Vs Stiffness