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Comparison of Manual and Automated Bend and Free Recovery Test Methods for Measuring the Active Austenite Finish Temperature of Nitinol Wires

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Abstract

The resulting active austenite finish (Af) temperatures of Nitinol round wires measured by two bend and free recovery methods, operator manual observation and ASTM F2082, are compared. Nitinol shape recovery and how it affects transformation temperature determination is also discussed.

Introduction

The transformation temperatures of Nitinol, specifically the active Af temperature, are a critical attribute to the final performance of a medical device. Historically, active A_f testing of medical grade Nitinol components has been performed via manual methods. These methods involve an operator visually observing 100% recovery upon heating the material after cold deformation. Test methods used to determine the thermal properties of Nitinol and the influence of the material on medical device performance has advanced significantly since the 1990's. ASTM F2082 was developed to automate and standardize active A_f temperature measurement techniques throughout the Nitinol industry [1]. Contrary to visual operator observation of material recovery, ASTM F2082 involves controlled imparted strain with displacement measured via camera or linear/rotary variable differential transducer upon heating. The resulting A_f value is then determined by the intersection of tangent lines ($A_{f\text{-}tan}$) on a displacement vs. temperature plot [2]. Stricter FDA regulations have encouraged a push toward an automated, less subjective, method of testing. For this reason, it is necessary to understand what correlation, if any, exists between the two methods.

Experimental Procedure

Nitinol round wires ranging in diameter from 0.011" to 0.058" were drawn under various processing conditions. Multiple Nitinol ingots with varying thermal properties were used to generate finished wires with active A_f temperatures spanning a ~80°C range. The active A_f of each sample was then measured by an operator via manual observation as well as ASTM F2082.

Results

The active A_f measured by both methods was plotted against one another to determine correlation. A trendline was plotted through the data set. A trendline showing a 1:1 correlation was also plotted for reference, Figure 1.

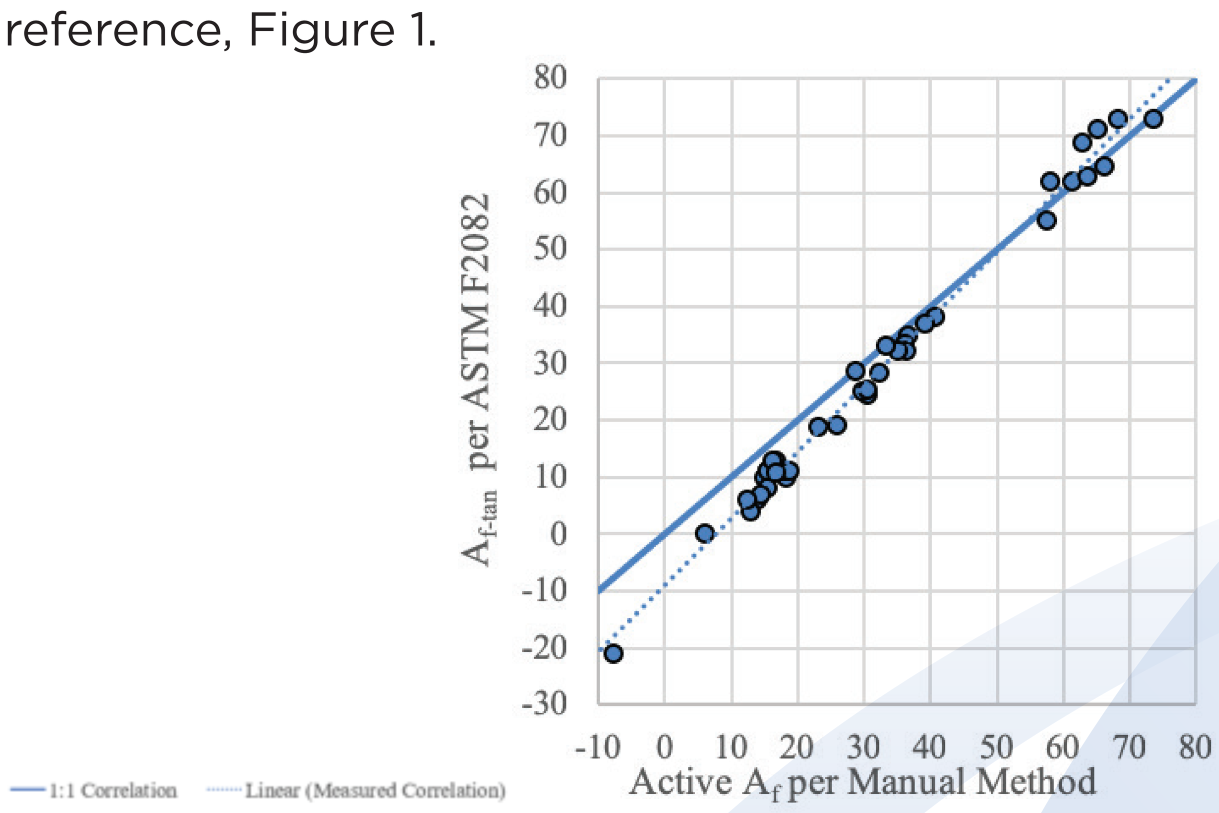

Figure 1. $A_{f\text{-}tan}$ per ASTM F2082 plotted vs. Manual Method

When comparing the manual bend and free recovery method to ASTM F2082, it is important to consider the shape of the displacement vs. temperature curve. A wider hysteresis as well as the presence of R-phase, will result in a more "sluggish" displacement of the wire. This is evident by a gradual slope and larger radius to recovery on the bend and free recovery curve. In contrast, a narrower hysteresis will result in a sharp transition to full recovery, Figure 2. The gradual recovery curves exhibit a larger offset between $A_{f\text{-}tan}$ per ASTM F2082 and when the operator would detect that the wire has stopped movement. The steep recovery curve displays a much smaller offset between these two values resulting in a greater chance the operator will detect that the wire has stopped moving and determine the active A_f closer to $A_{f\text{-}tan}$ per ASTM F2082.

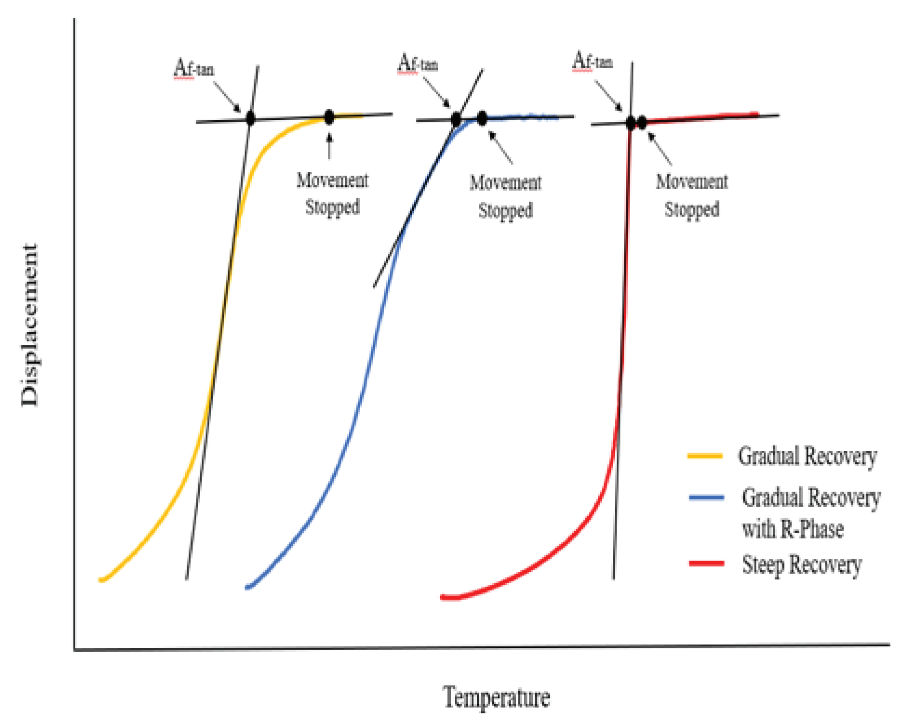

Figure 2. Displacement vs. temperature curves showing gradual and steep recovery

Conclusion

Due to the varying shape of the recovery curve upon heating Nitinol wire after deformation, a 1:1 correlation between manual and automated methods of measuring active A_f could not be established. Also, there does not appear to be a consistent offset between the two methods.

When switching historical parts from the manual to the ASTM method of measuring active A_f, it is recommended a correlation study be performed to determine new material specification limits based on previously established accepted product performance.

References

[1] *Standard Test Method of Determination of Transformation Temperature of Nickel-Titanium Shape Memory Alloys by Bend and Free Recovery*, ASTM F2082-16, ASTM, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959.

[2] Rice, C., and F. Sczerzenie. "DESIGN AND PERFORMANCE OF A FUNCTIONAL AF TESTER." SMST-97: *Proceedings of the Second International Conference on Shape Memory and Superelastic Technologies*. ASM International, 1997.