Special heat treatment for achieving Superelasticity (*)

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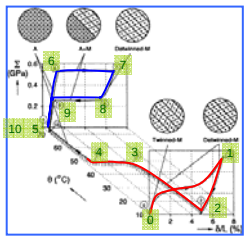
OVERVIEW:

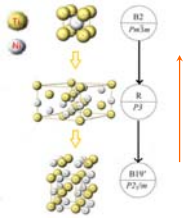
Usually, elasticity in any metal or alloy is observed to be a recoverable strain up to 0.5%. However, in case of equi-atomic Nickel-Titanium (Ni-Ti) alloy, the elastic limit can be recorded up to 10%. Hence, the property is known as, 'superelasticity'. The process of achieving this property involves optimized chemical composition and heat treatments. For the present study, Ni(51.0at%)-Ti alloy wire of diameter 3.1 mm, in straight annealed condition was selected. One specimen was maintained in the as-received (AR) condition. Heat treatments were performed in two ways: (i) solution annealed at 900 ºC for 20 min (SA900) and (ii) solution annealed at 900 ºC followed by aging at 260 ºC for 15 h (SA900+Ann260); all heat treatments were followed by water quenching to room temperature (RT). The alloy in the AR condition; during the Differential Scanning Calorimeter (DSC) study, while cooling, exhibited two-stage phase transformation below room temperature (RT) and, while heating, overlapped two-stage phase transformation finishing at around 37ºC was observed. For the specimen solution annealed at 900ºC (SA900), both while cooling and heating, one-stage phase transformation below RT was observed. Further aging at 260ºC for 15 h, after solution annealing at 900 ºC (SA900+Ann260), makes the specimen exhibit multi-stage phase transformation in a wide temperature range. Mechanical testing of the material in the different conditions using a Universal Tensile Machine (UTM), has shown that, among the tested specimens, HTT900+Ann260 showed SE with higher strain recovery. Further, XRD studies were undertaken to study the evolution of the structures. Results are interpreted in an effort to correlate the thermal phase transformation with the observed SE behaviour.

Shape Memory Effect (SME) and Superelasticity (SE)



(0) to (4) - SME
(5) To (10) - SE

It is due to crystallographic phase transformation:



In equi-atomic Ni-Ti alloy

» Phase transformation from *high-temperature cubic* (B2) austenitic phase structure to a *monoclinic* (B19') low temperature martensite phase, with the *trigonal* R-phase occurring in an intermediate temperature range, depending on the thermomechanical history of the alloy.

Some basic conditions for SE

- Chemical composition of the alloy
- Heat treatments (solution annealing, aging, rate of cooling etc.)
- Mechanical treatments (cold- , hot-working, severe plastic deformation etc.)
- Thermomechanical treatments (cycling etc.)

Heat treatment is the most economic and effective method to maneuver the properties of metals and alloys

Material used:

Nickel-Titanium (Ni-Ti) Procured from Memory-Metalle GmbH, Germany

Chemical Composition: Ni(51.0at%)-Ti
Wire, diameter 3.124 mm
Straight annealed condition

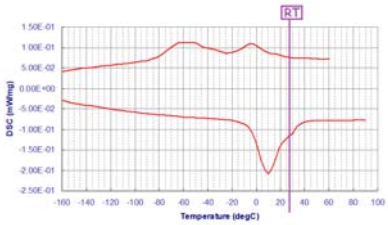
In the present study > > >

Three different conditions of the Ni-Ti alloy were studied:
(i) as received (AR),
(ii) solution annealed at 900 °C for 20 min and
(iii) solution annealed at 900 °C followed by aging at 260 °C for 15 h

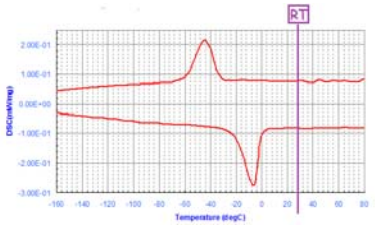
Characterization techniques:

- Differential Scanning Calorimeter (DSC).
- XRD studies were undertaken to study the evolution of the structures.
- Mechanical testing of the material in the different conditions using a Universal Tensile Machine (UTM).

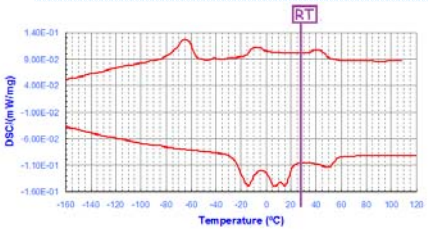
DSC thermogram: for AR specimen



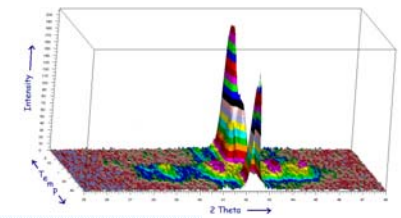
DSC thermogram: Solution annealed at 900°C



DSC thermogram: Solution annealed at 900°C + aging at 260°C for 15 h

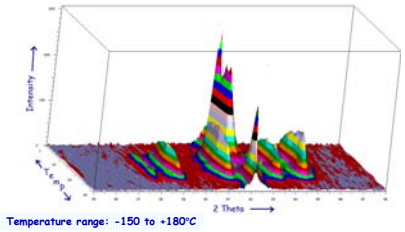


XRD thermogram: for AR specimen



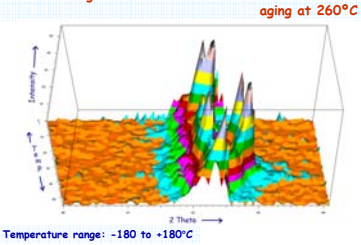
Temperature range: -160 to +180°C

XRD thermogram: Solution annealed at 900°C



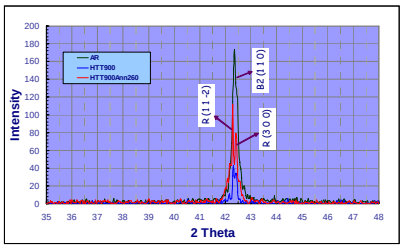
Temperature range: -150 to +180°C

XRD thermogram: Solution annealed at 900°C + aging at 260°C for 15 h

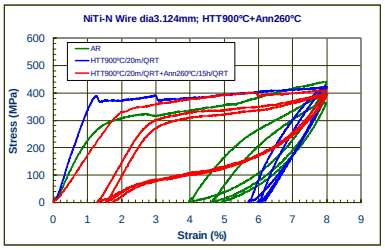


Temperature range: -180 to +180°C

XRD thermograms: All the three specimens at RT



SE Result:



Summary:

- **SE test** : Straining upto 8% leads to
  (i) for AR condition, recovery upto around 6%.
  (ii) for Annealing at 900°C condition, recovery upto around 4.5%.
  (iii) for Annealing at 900°C followed by aging at 260°C condition, recovery upto around 1.5%.

Appreciable superelasticity is achieved after solution treatment at 900°C followed by aging at 260°C for 15 hrs.

(*) Oral presentation by KKM at IUMRS-ICA 2013, December 2013

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RELATED PUBLICATIONS:

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3. Ageing effects on phase transformations in NiTi alloys, K. K. Mahesh, F. M. Braz Fernandes and Rui J. C. Silva, ESOMAT-2009 - The 8th European Symposium on Martensitic Transformations (ESOMAT-2009), Published by EDP Sciences, ISBN: 978-2-7598-0480-1.

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