Progress report

Thermomechanical fatigue of Boeing 60-NiTi

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Progress overview

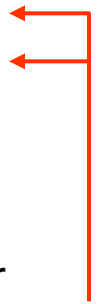
- One 60-NiTi specimen left to be tested: end of scoping experiment

- Scoping experiment presents to few data with not enough differences between the two set of heat treatment to decide which HT is better

Summary of scoping experiment

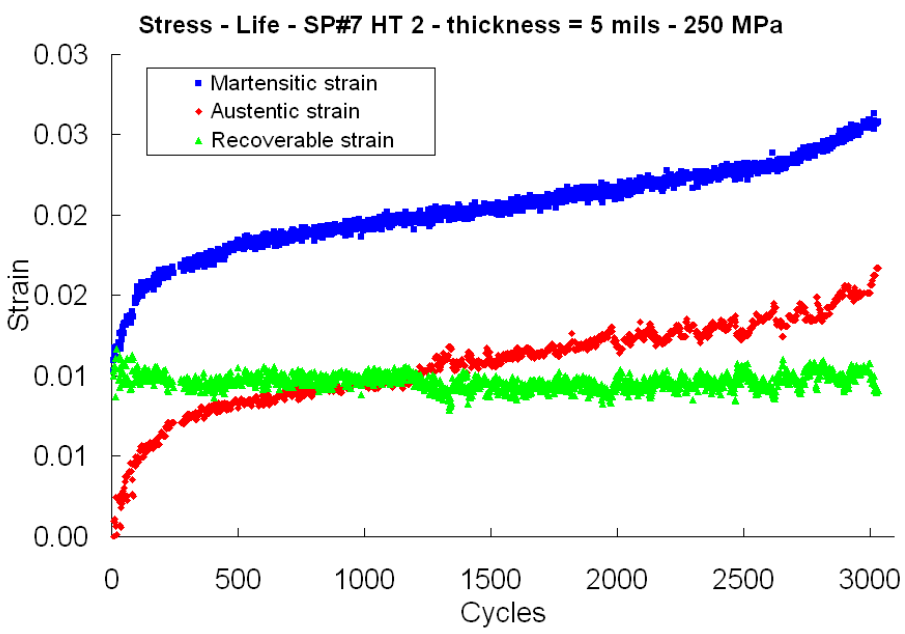
Two additional test are performed under 200MPa, one is still running at 13000 cycles so far, one is to be completed by next week

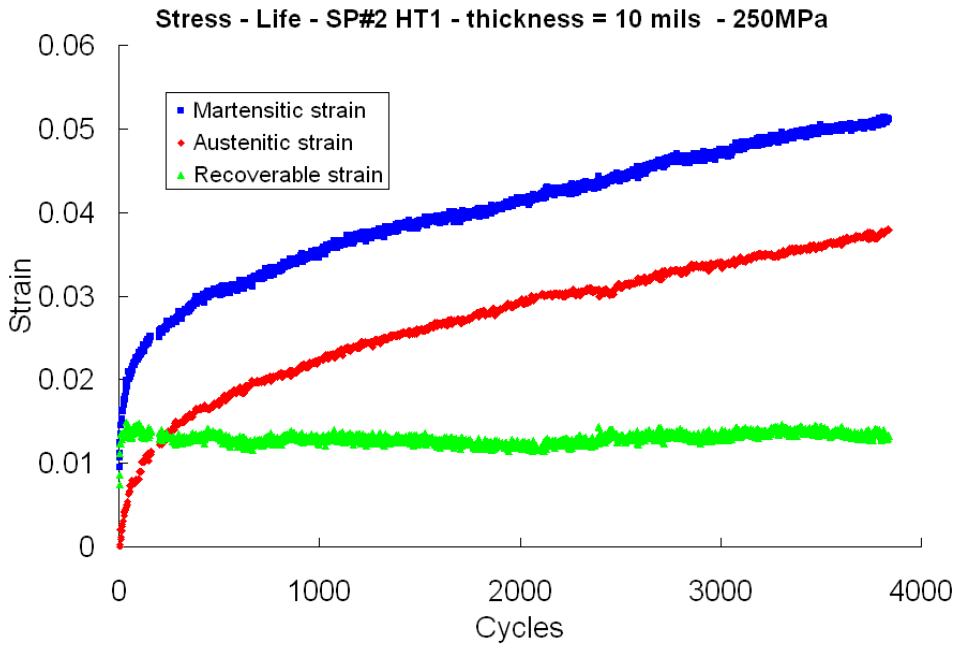
Run order	Specimen #	Heat treatment	Thickness (mils)	Applied stress (MPa)
1	*SP# 6 HT2*	*A2*	*10*	*226*
2	*SP# 4 HT2*	*A2*	*5*	*107*
3	*SP# 3 HT1*	*A1*	*5*	*204*
4	*SP# 7 HT1*	*A1*	*15*	*243*
5	*SP# 5 HT2*	*A2*	*5*	*103*
6	*SP# 5 HT1*	*A1*	*10*	*90*
7	*SP# 3 HT2*	*A2*	*15*	*142*
8	*SP# 7 HT2*	*A2*	*5*	*250*
9	*SP# 2 HT1*	*A1*	*10*	*250*
10	SP# 4 HT1	A1	15	203
11	SP# 2 HT2	A2	15	199
Heat Treatments		A1	1 hr @ 850°C, 1 hr @ 450°C	
		A2	1 hr @ 850°C, 20 hrs @ 450°C	



Last two specimens to be tested under ~200MPa stress level

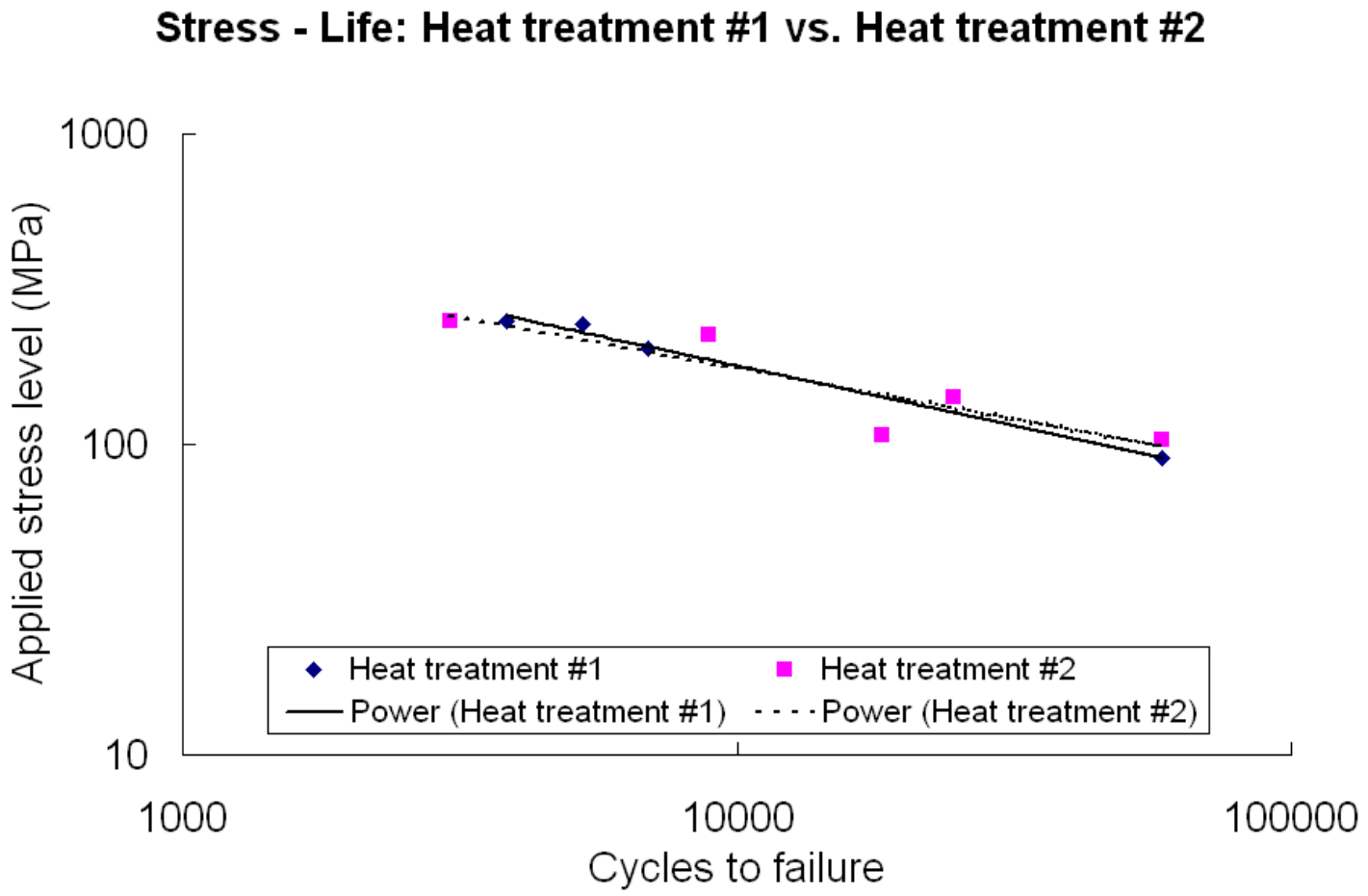
Run Order #8 and #9





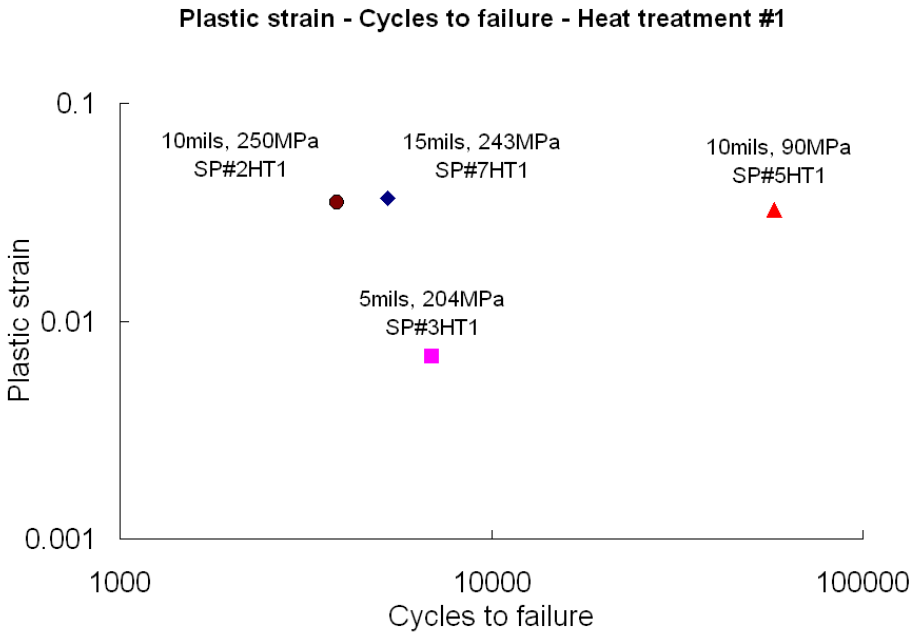
- **Thin specimens display better stabilization whereas thick specimens have tendency to show creep like behavior**
- **Recoverable strain is stable in all cases**

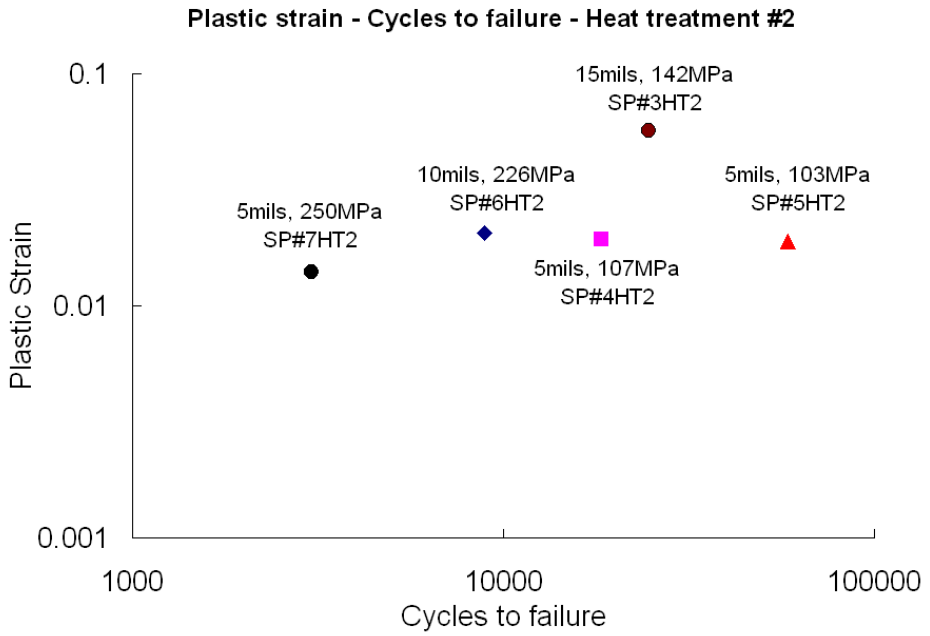
Stress – life: first results



- Not enough fatigue data to draw conclusions on the performances of the two different heat treatments

Plastic strain: first results





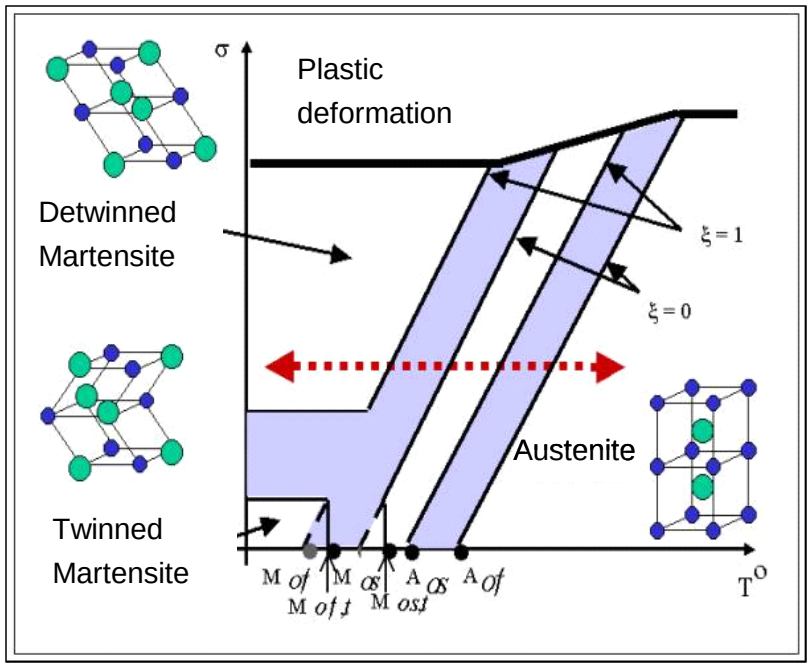
- Saturated plastic strain values at failure do not show trend in terms of amount of plastic strain related to the applied stress level
- However, the first observation we make is a higher plastic strain level attained for thicker specimens

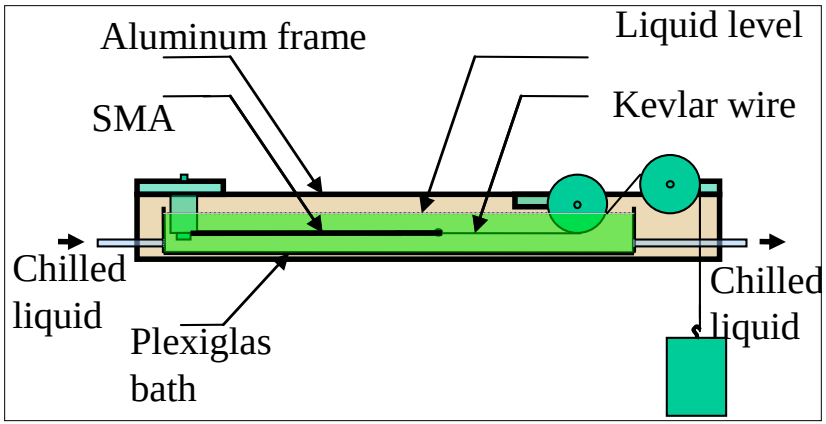
Future work

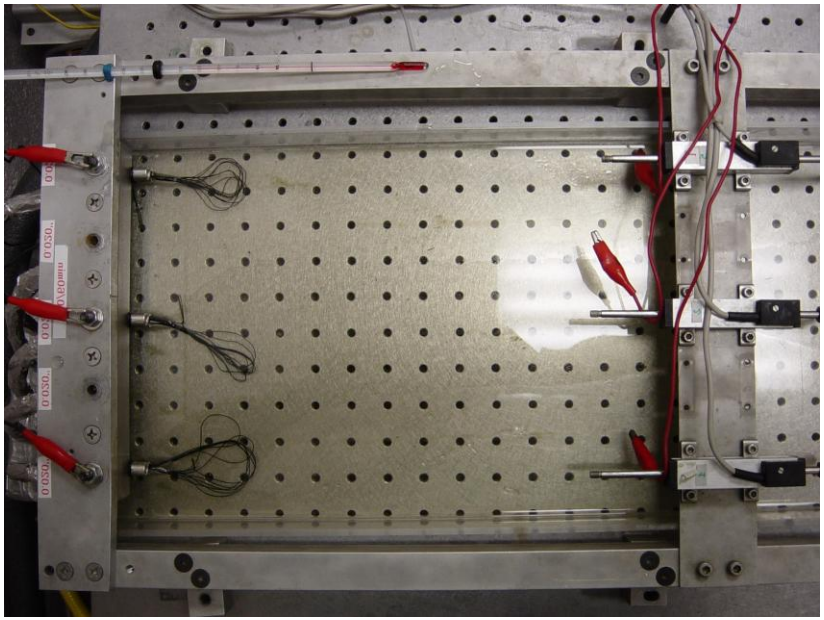
- Analysis the failed specimens and their microstructure for better assessment of the differences between HT#1 and HT#2
- Reproduce tests with questionable results
- Equipment upgrade to be ready when next series of specimens is ready for fatigue testing

Experimental Setup (1)

Uniaxial isobaric fatigue testing for SMA actuators under constant applied load



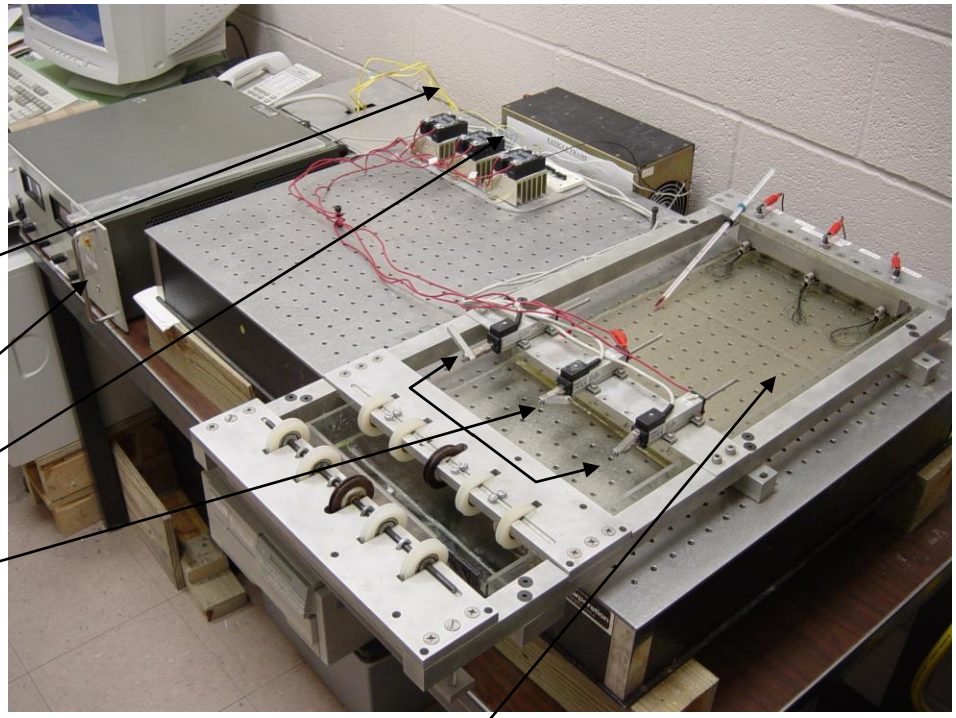




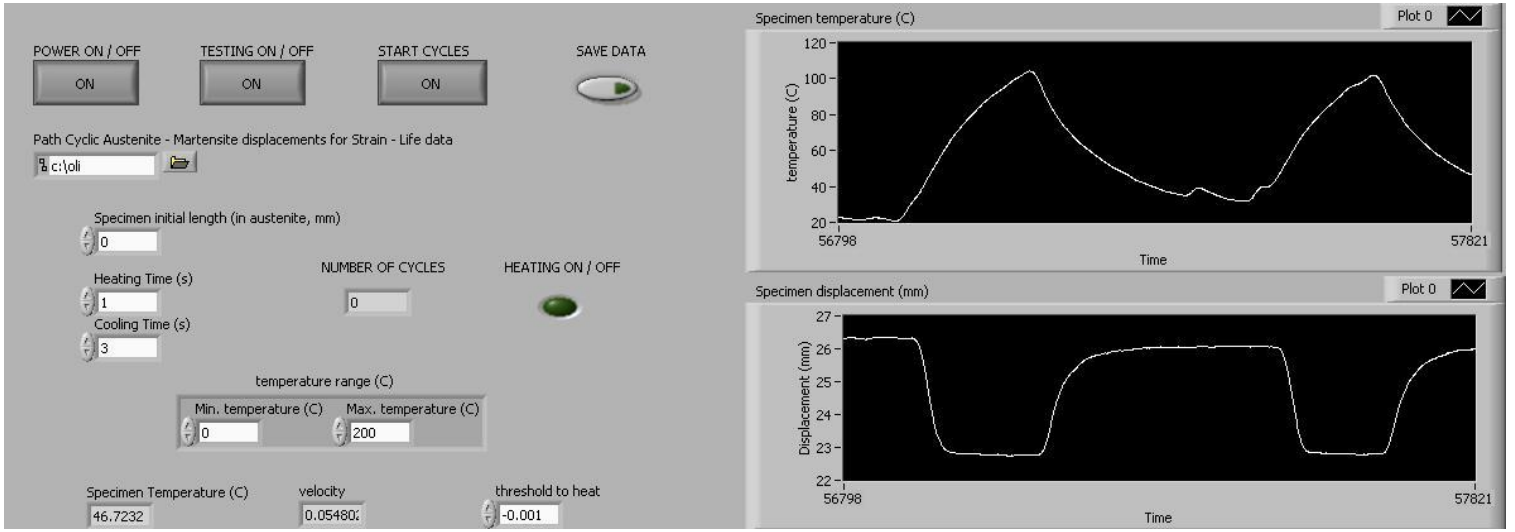
- Thermally induced transformation cycles
- Constant load
- Complete and partial phase transformation cycles

Experimental Setup (2)

- Thermal actuation:
  - Resistive heating in SMA specimens using DC power supply
  - Cooling is achieved using forced convection of a waterless coolant (ethylene and propylene glycol)



Labview control program



Temperature

Displacement

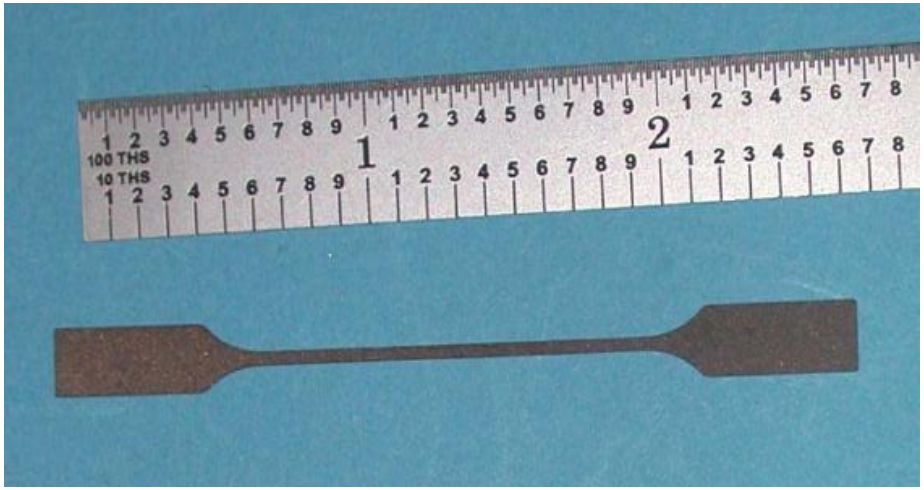
The temperature and displacement is monitored real-time to assess onset and end of transformation

Range of experiments

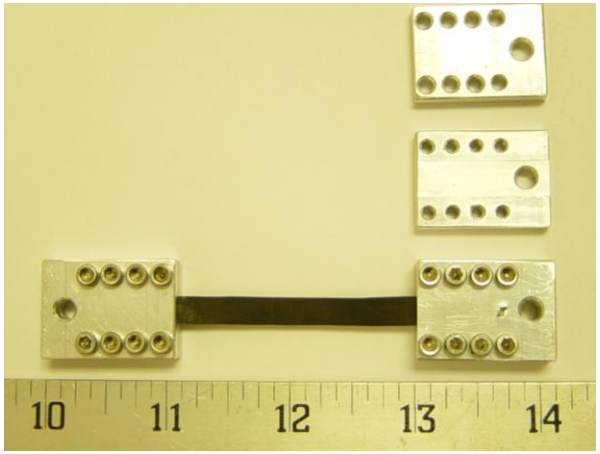
Fatigue Test Matrix		Applied stress		
Heat treatment	Cross section ($mils^2$)	50 MPa	150 MPa	250 MPa
1 hr.@ 850 C furnace cool, 1 hr.@ 450 C water quenched	50 x 5	6	6	6
	50 x 15	6	6	6
1 hr.@ 850 C furnace cool, 20 hrs.@ 450 C water quenched	50 x 5	6	6	6
	50 x 15	6	6	6

Specimens and Clamping

- Specimens are cut into thin dogbones with corner radii to remove stress concentration at the grips



- Grips designed to allow testing for dogbone specimens



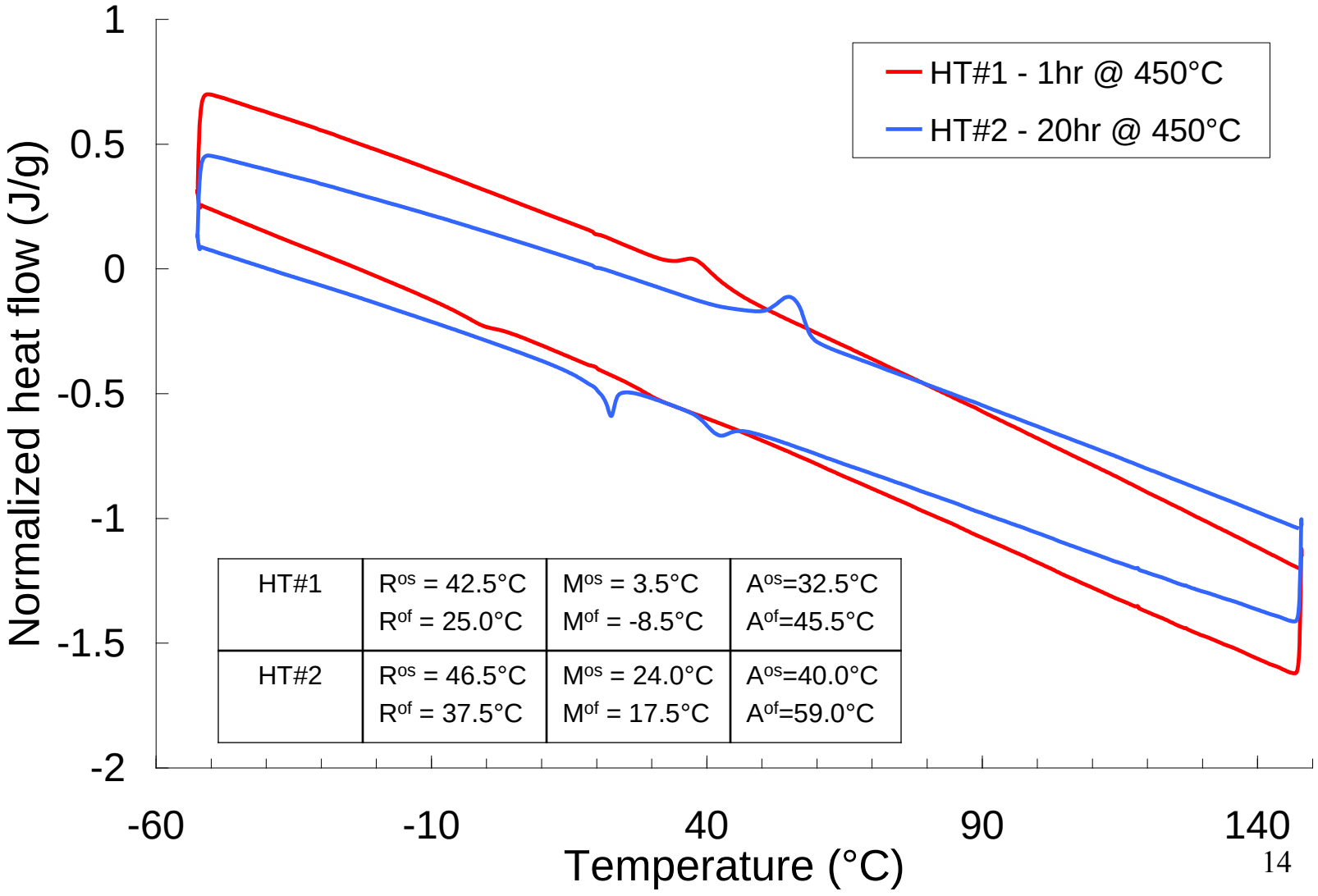
Zero stress transformation temperatures (1)

A differential scanning calorimeter (DSC) was utilized to identify the transformation temperatures of 60-NiTi specimens, for the two different heat treatments.

Recall - HT#1: 1hr @ 850°C, furnace cool to room temperature
1hr @ 450°C, water quenched

- HT#2: 1hr @ 850°C, furnace cool to room temperature
20hrs @ 450°C, water quenched

Zero stress transformation temperatures (2)

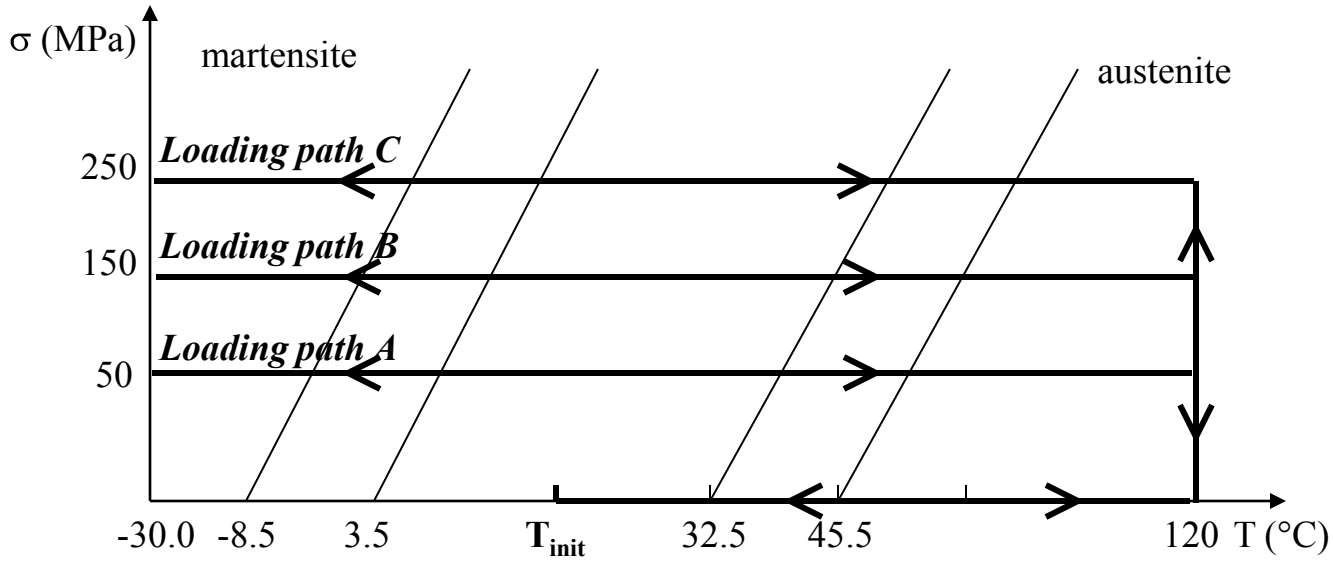


HT#1	R^{os} = 42.5°C R^{of} = 25.0°C	M^{os} = 3.5°C M^{of} = -8.5°C	A^{os}=32.5°C A^{of}=45.5°C
HT#2	R^{os} = 46.5°C R^{of} = 37.5°C	M^{os} = 24.0°C M^{of} = 17.5°C	A^{os}=40.0°C A^{of}=59.0°C

Quasi-static isobaric hysteresis loop(1)

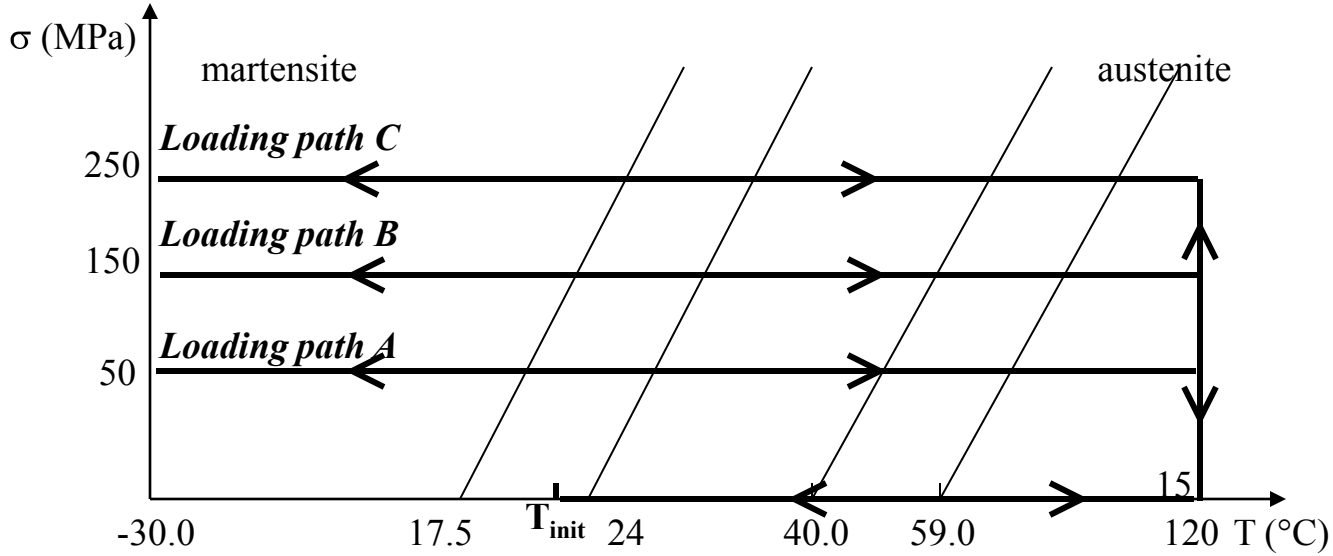
Heat treatment #1

T_{init}: room temperature



Heat treatment #2

T_{init}: room temperature



Quasi-static isobaric hysteresis loop (2)

- HT#1 results show wider martensitic phase transformation region resulting in gradual transformation with little non recoverable strain while HT#2 displays narrower martensitic phase transformation region with in this case significant non recoverable strain under 250MPa constant stress.