TiiMS
TEXAS INSTITUTE FOR INTELLIGENT BIO-NANO MATERIALS AND STRUCTURES FOR AEROSPACE VEHICLES
A NASA University Research, Engineering and Technology Institute (URETI)

Transformation Behavior in TiPdNi High Temperature Shape Memory Alloys

Parikshith K. Kumar

Dr. Dimitris C. Lagoudas

Aerospace Engineering, Texas A & M University

ASME Applied Mechanics and Materials Conference
June 3-7, 2007

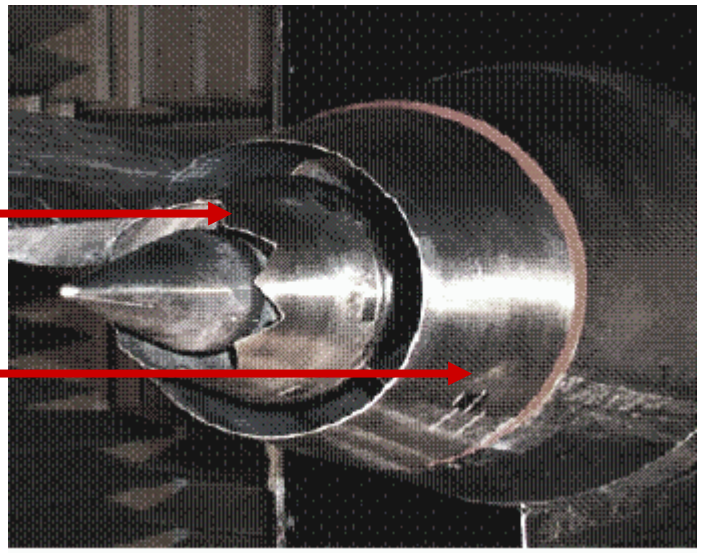
• Funded by the National Aeronautics and Space Administration
• Administered by the Texas Engineering Experiement Station
• A collaborative effort among: Prairie View A&M University | Rice University | Texas A&M University | | Texas Southern University | University of Houston | University of Texas - Arlington

Presentation outline

- Motivation for HTSMAs
- Review of previous work
- Specimen fabrication and experimental setup
- Thermomechanical testing of HTSMA
- Summary
- Future work

Motivation for developing HTSMA actuators

Need for reliable high force actuators capable of working under high temperature (above 100℃) environment



<u>Requirements on HTSMA:</u>

Transformation strain : ≈ 2%

Operating stress levels : 100 MPa and higher

Operating temperatures: 300 – 500 ℃

Applications in the fields of Aerospace & Oil industries.

Selection of HTSMA

- HTSMAs can be created by addition of different ternary elements such as Pd, Pt, Hf or Zr to binary NiTi

A small sample of high temperature SMAs

Composition	Mf (C)	Ms (C)	As (C)	Af (C)	Reference
Ti50Ni20Pt30	537	619	626	702	P.G.Lindquist et al. 1990
Ti50Pd40Ni10	387	403	419	427	P.G.Lindquist et al. 1990
Ti33Ni47Zr20	205	275	265	330	S.F.Hsieh et al. 1998
Ti36Ni49Hf15	148	179	216	231	X.L.Ming et al. 1999,2002

(NiTi)-Pd/Pt alloys have been extensively studied by Ronald Noebe & coworkers at NASA Glenn research center.

$Ti_{50}Pd_{40}Ni_{10}$ HTSMA – Literature review

This particular composition has been chosen :

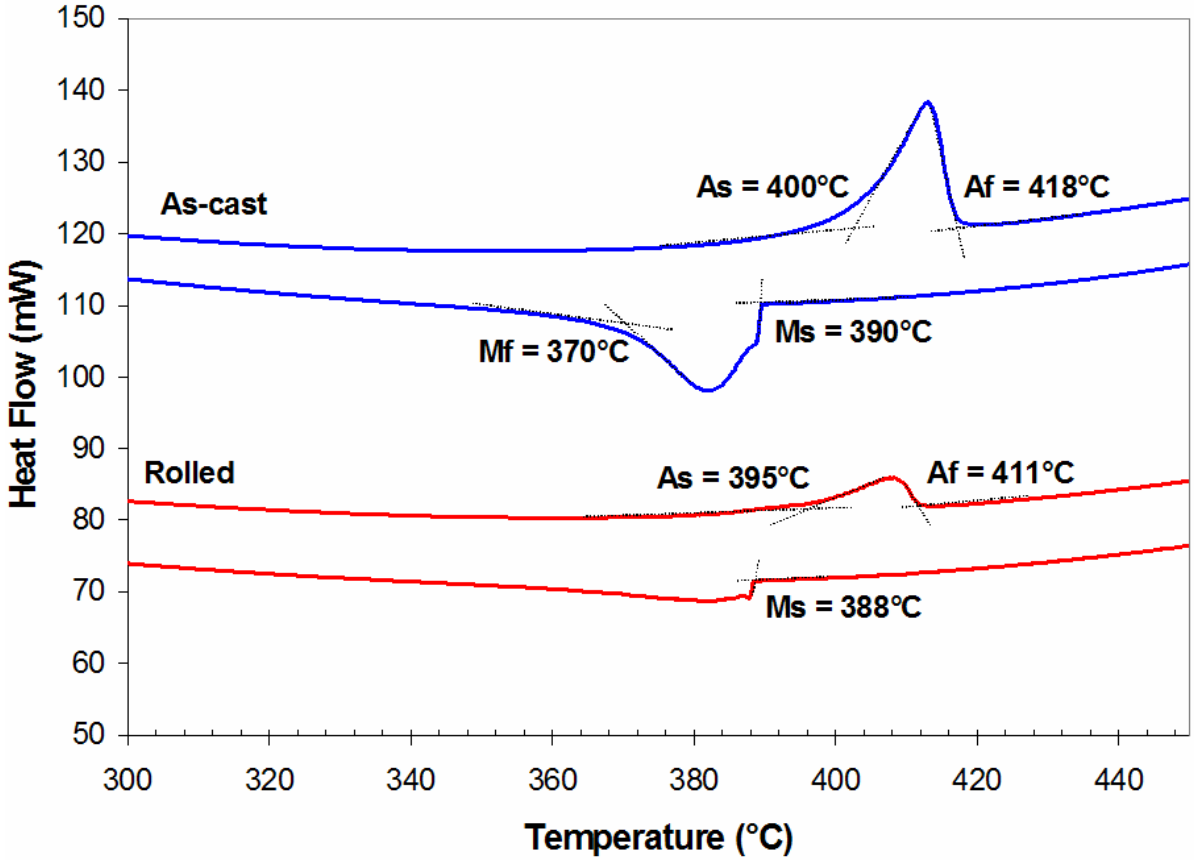
- High transformation temperatures (Mf = 387 ℃, Af = 4 27 ℃) [Lindquist et al., 1990].
- Recoverable strain of approximately 3.0 % (under no load) [Goldberg et al., 1995].

Previous work on $Ti_{50}Pd_{40}Ni_{10}$:

- Thermo-mechanical treatment [Goldberg et al., 1995].
- Recovery and recrystallization [Xu et al., 1997].
- Effect of aging [Cai et al., 1999].
- Microstructure studies [Xu et al., 1997].
- Work characteristics [Kumar et al., 2006, Padula II et al., 2006].

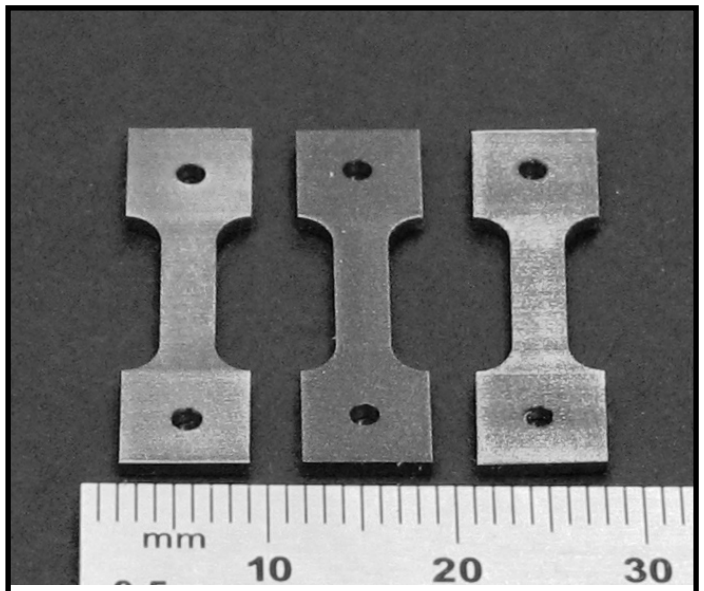
Transformation temperatures - $Ti_{50}Pd_{40}Ni_{10}$

Nominal composition of $Ti_{50}Pd_{40}Ni_{10}$ alloy fabricated by vacuum arc melt technique.

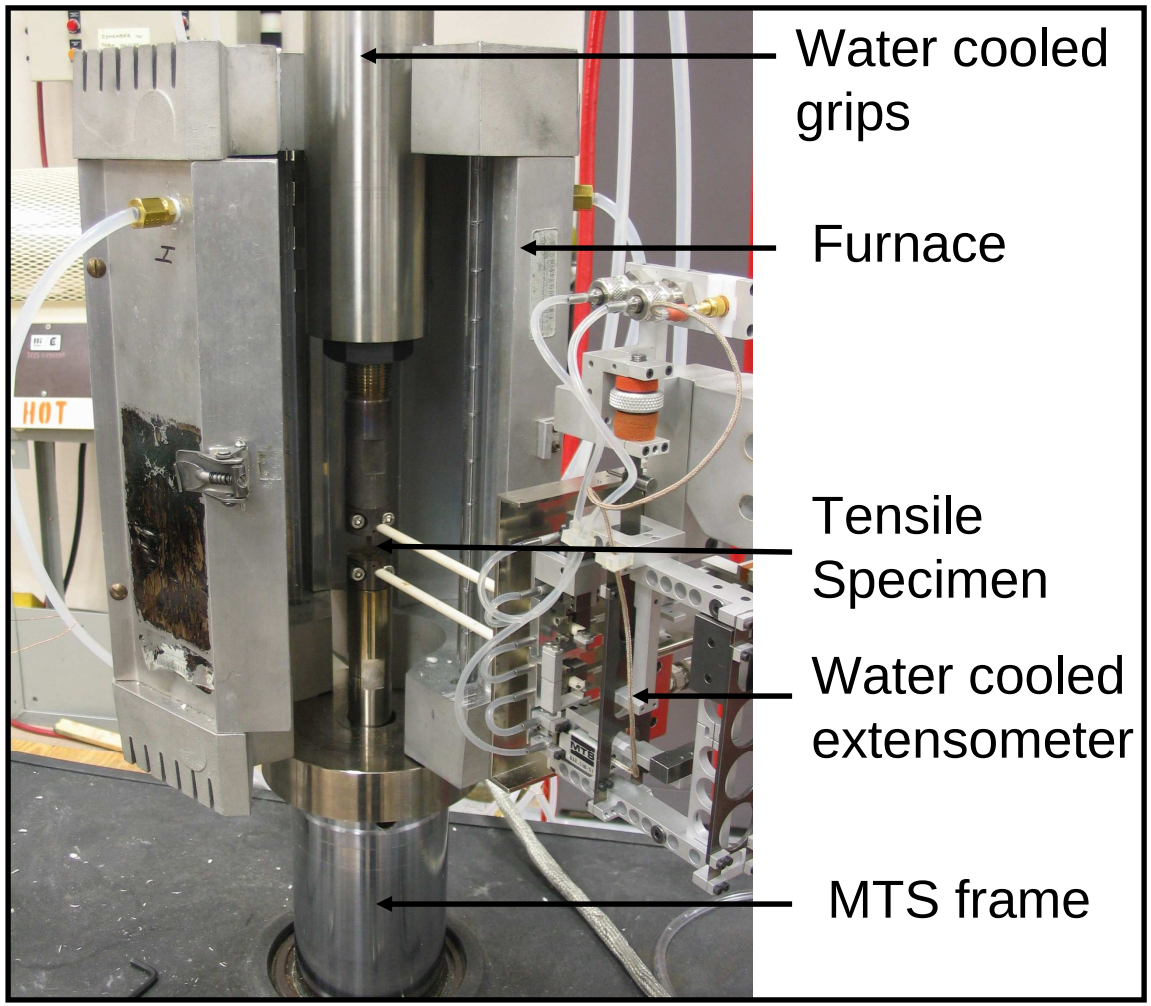


Hot rolled at 900℃ (30% reduction in thickness)

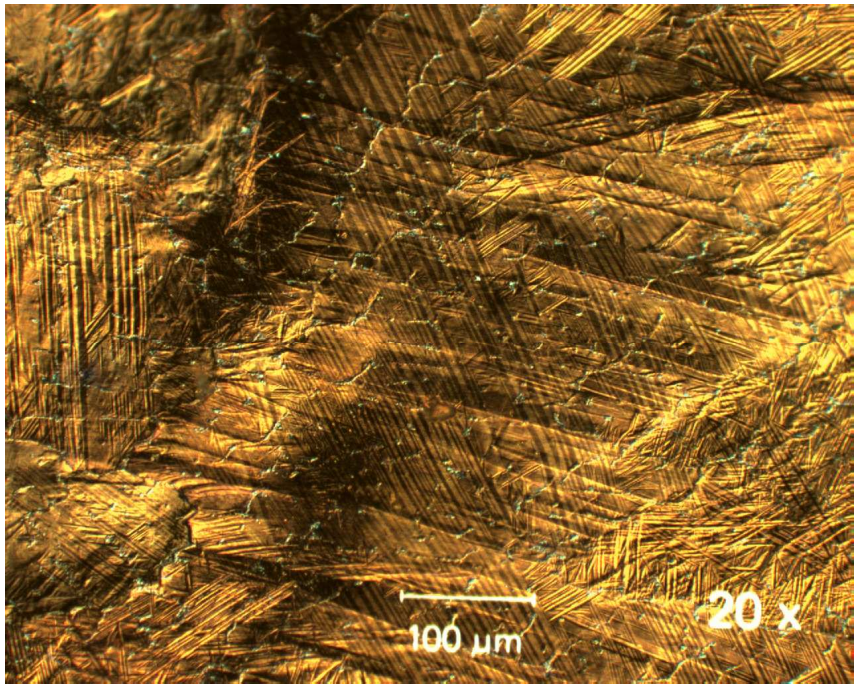
Specimens and experimental setup



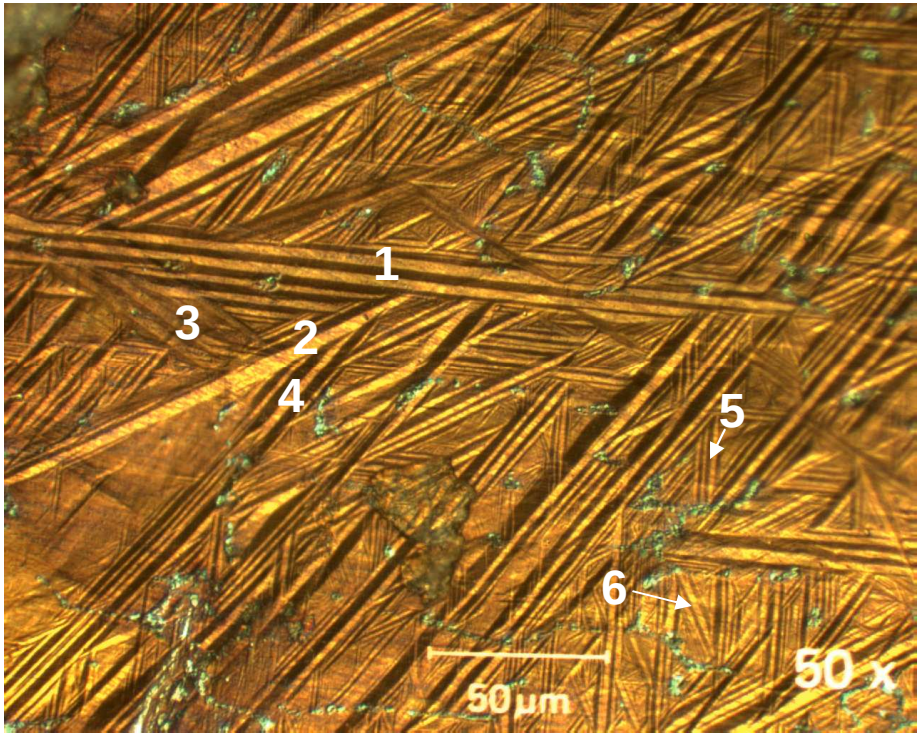
EDM cut tensile specimens



Microstructure of specimen

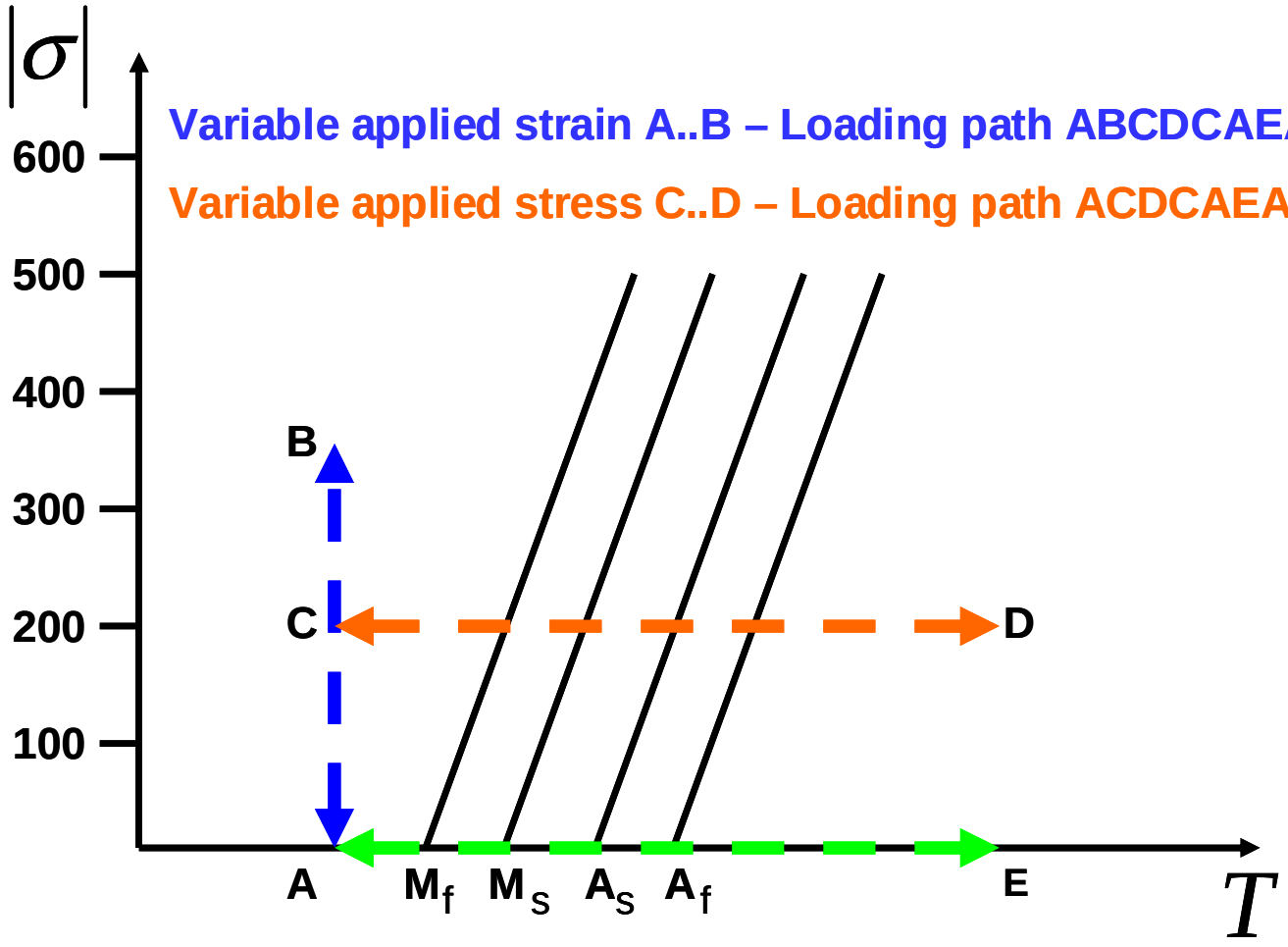


Typical grain size in the material is of the order of 100 – 150 µm



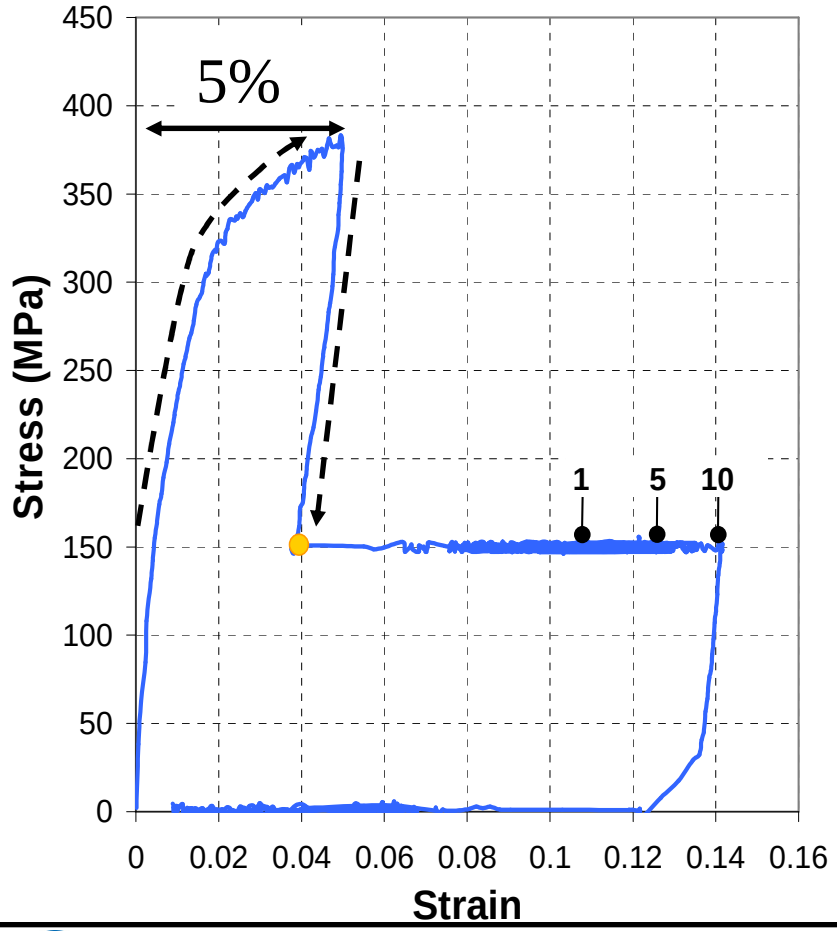
Microstructure within a grain showing all 6 martensitic variants

Thermomechanical loading paths: Effect of applied strain and applied stress

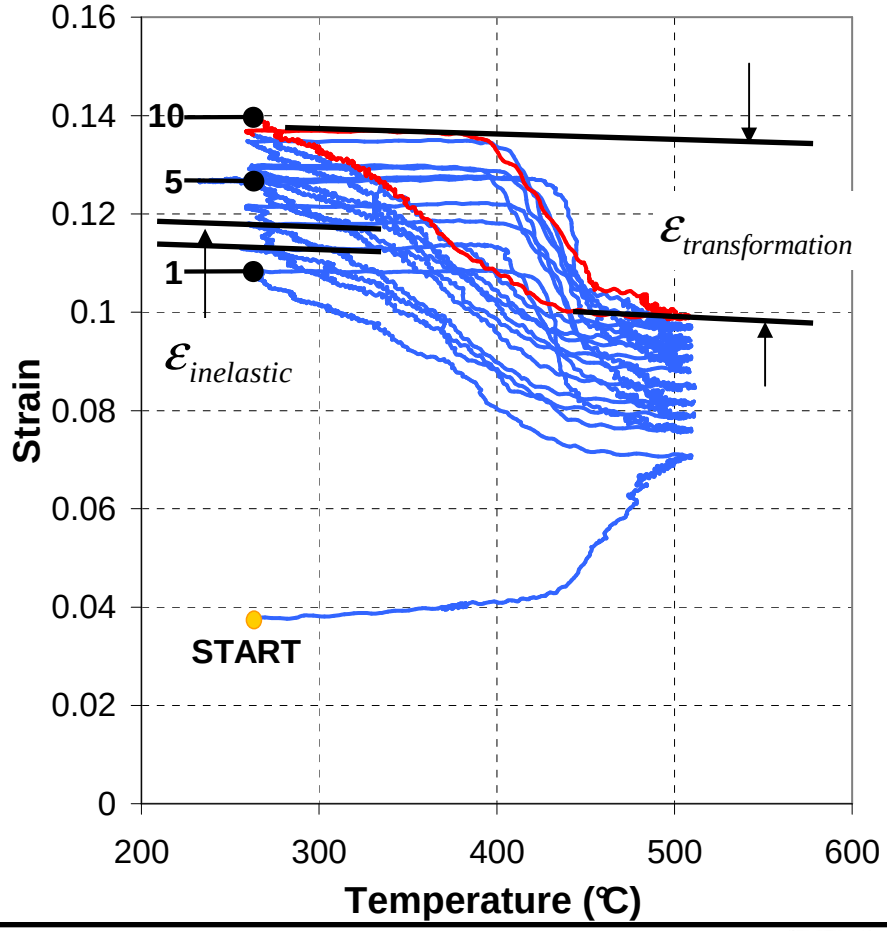


5% applied strain, thermal cycling under stress of 150 MPa

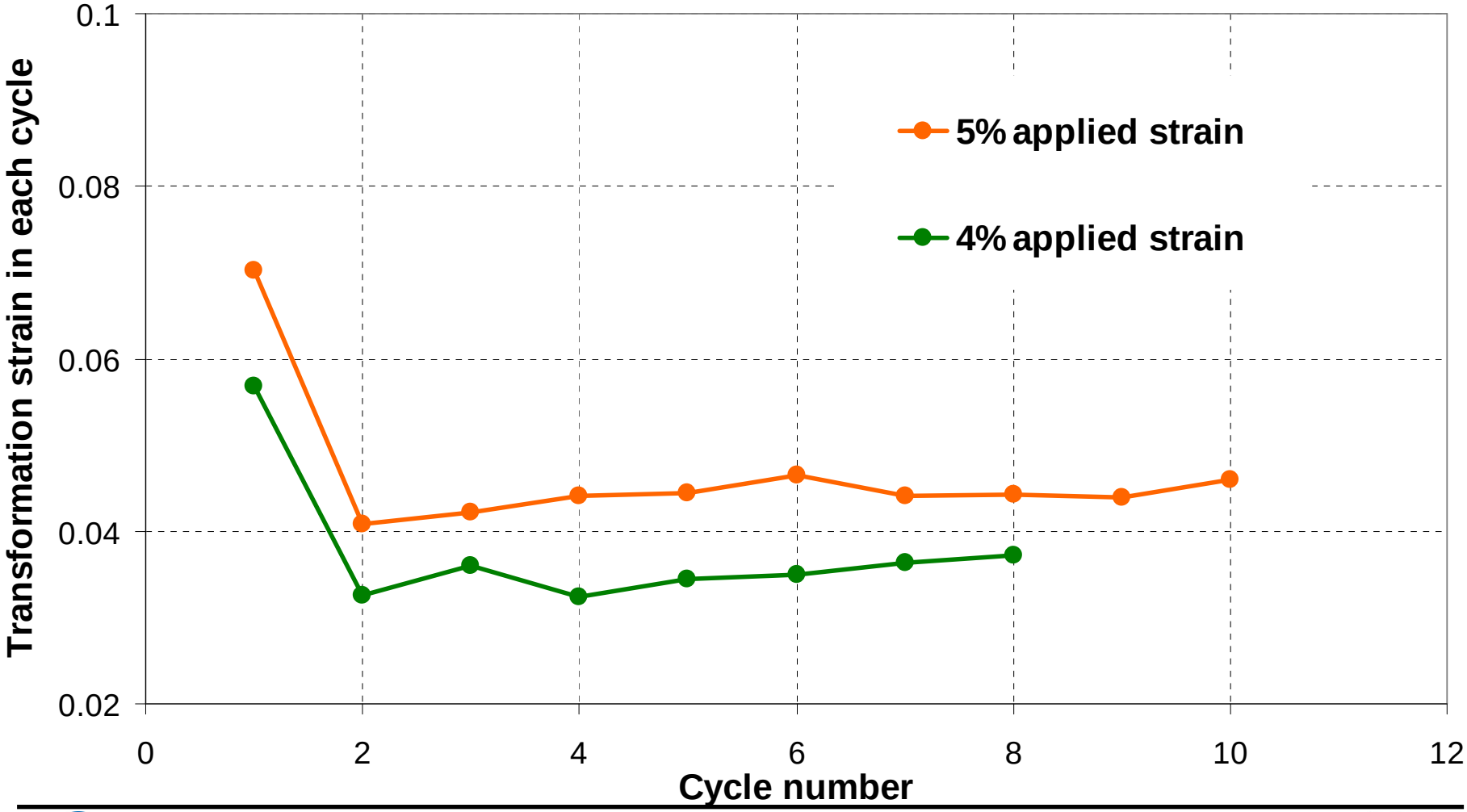
Isothermal loading at 260℃



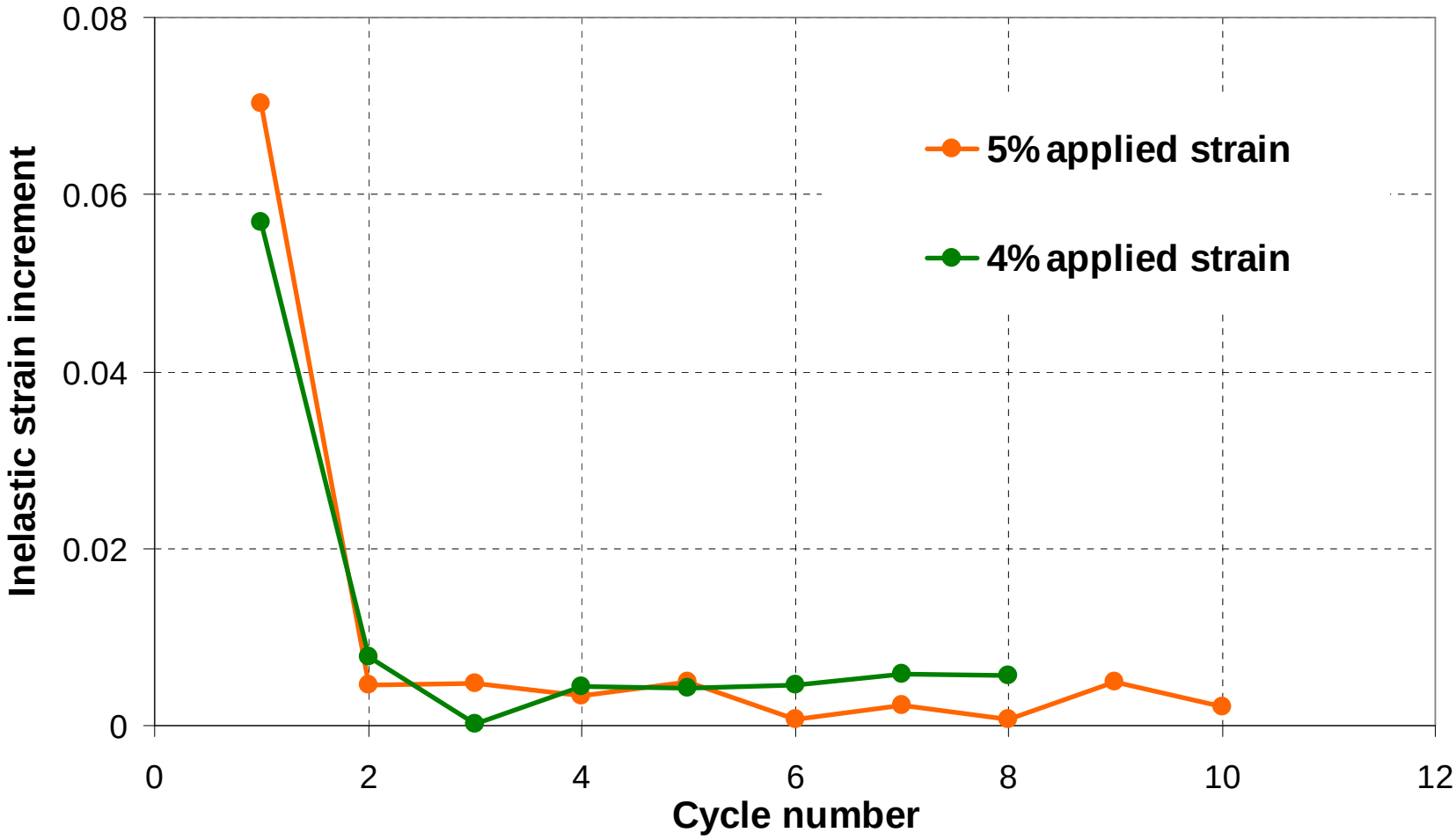
At 150 MPa



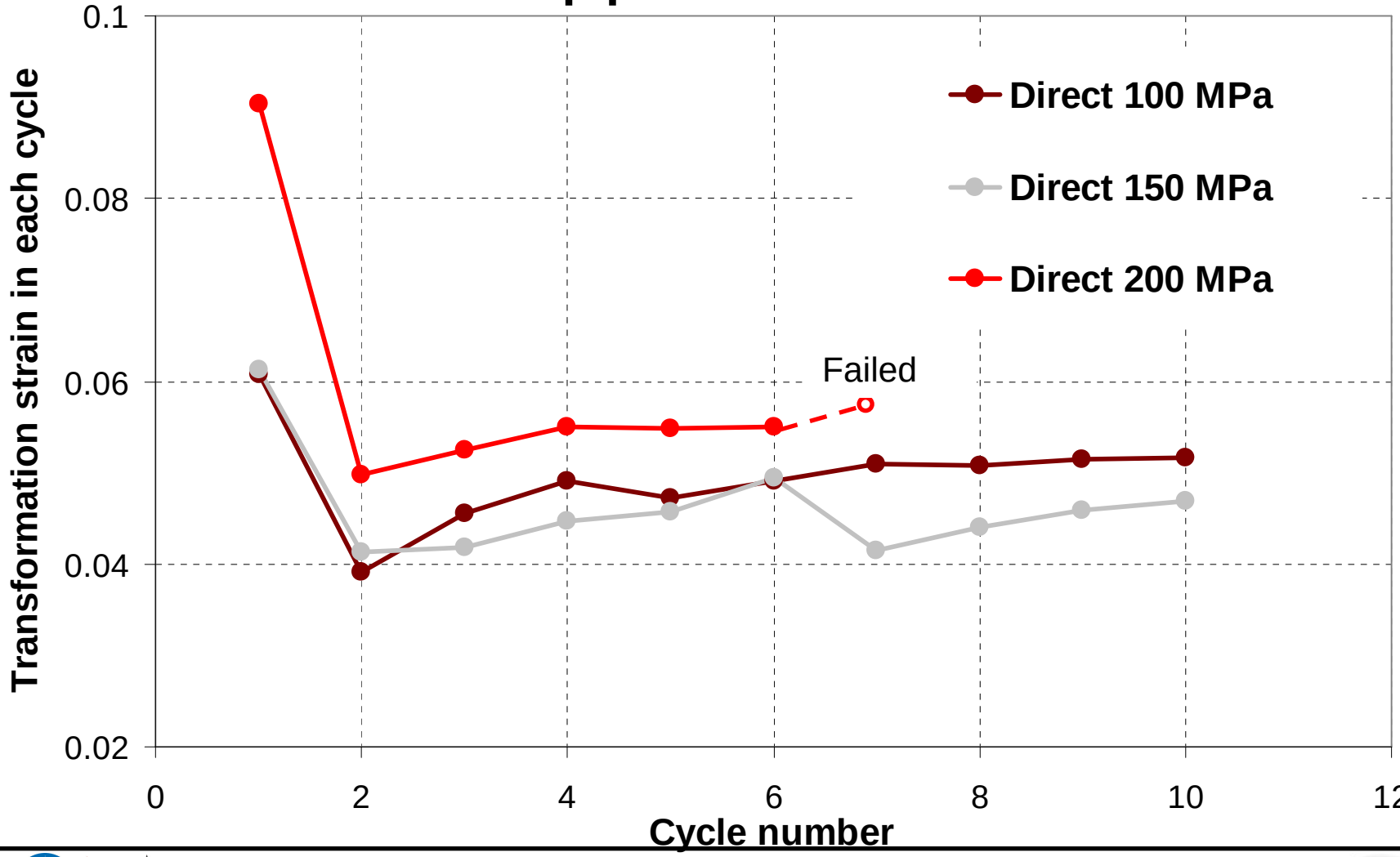
Transformation strain evolution: Effect of applied strain (stress 150 MPa)



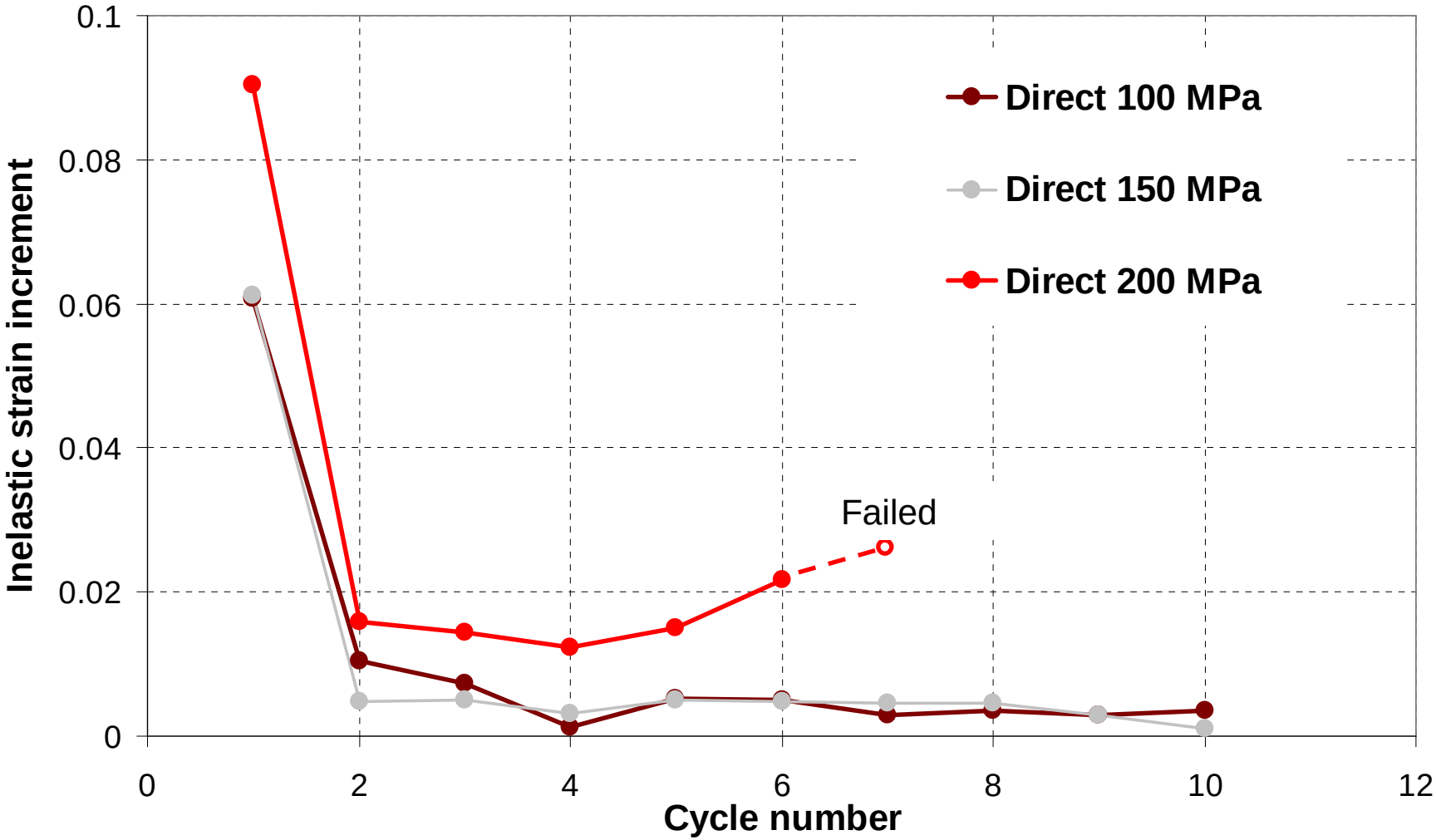
Inelastic strain evolution: Effect of applied strain (stress 150 MPa)



Transformation strain evolution: Effect of applied stress

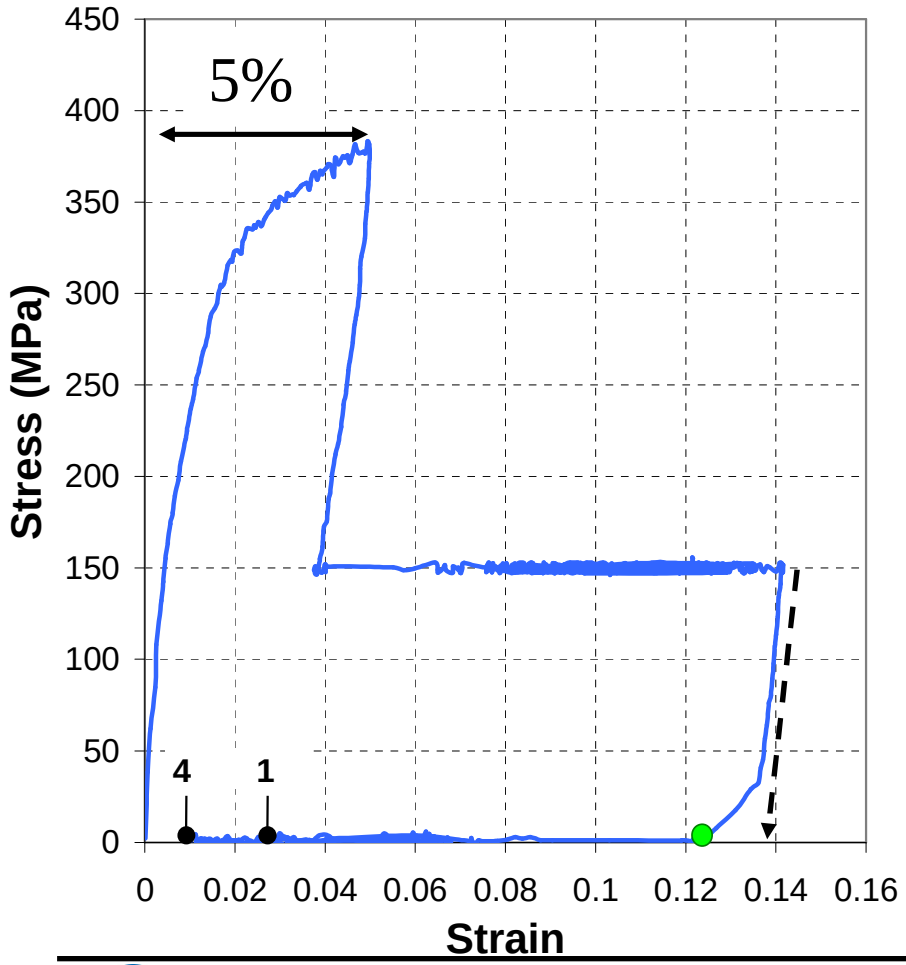


Inelastic strain evolution : Effect of applied stress

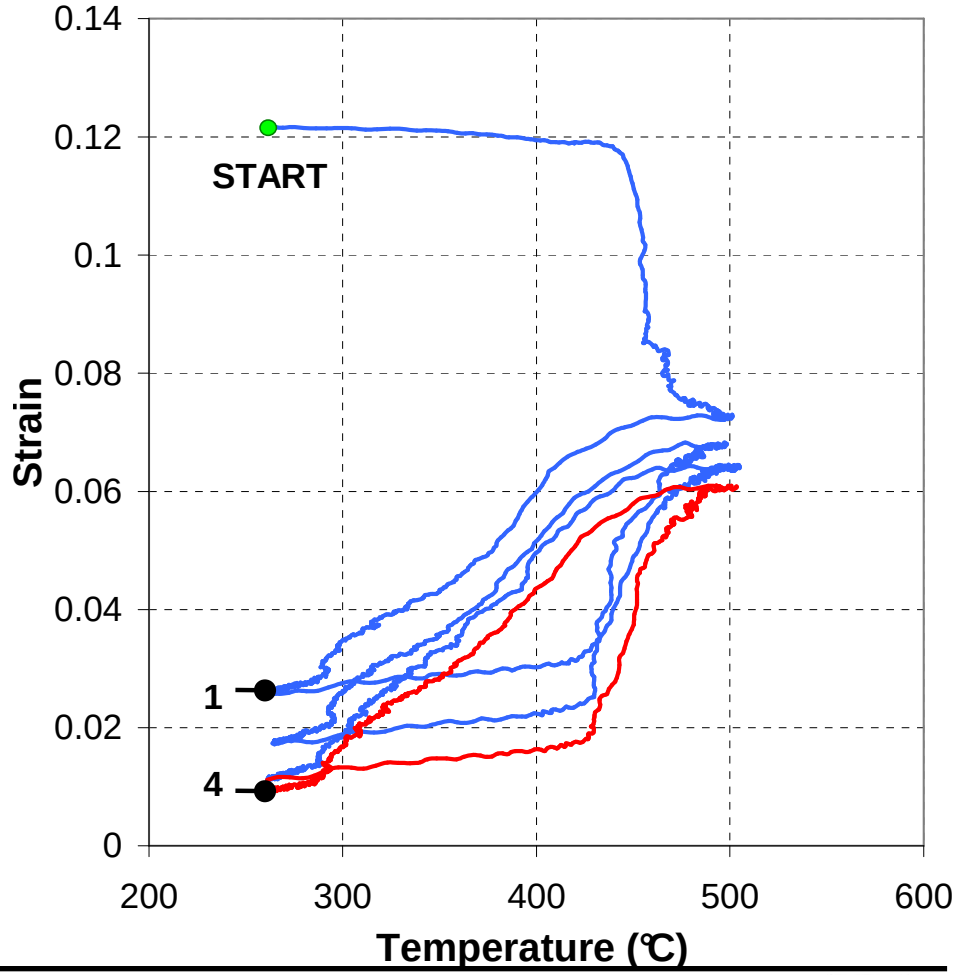


5% applied strain, thermal cycling under stress of 0 MPa

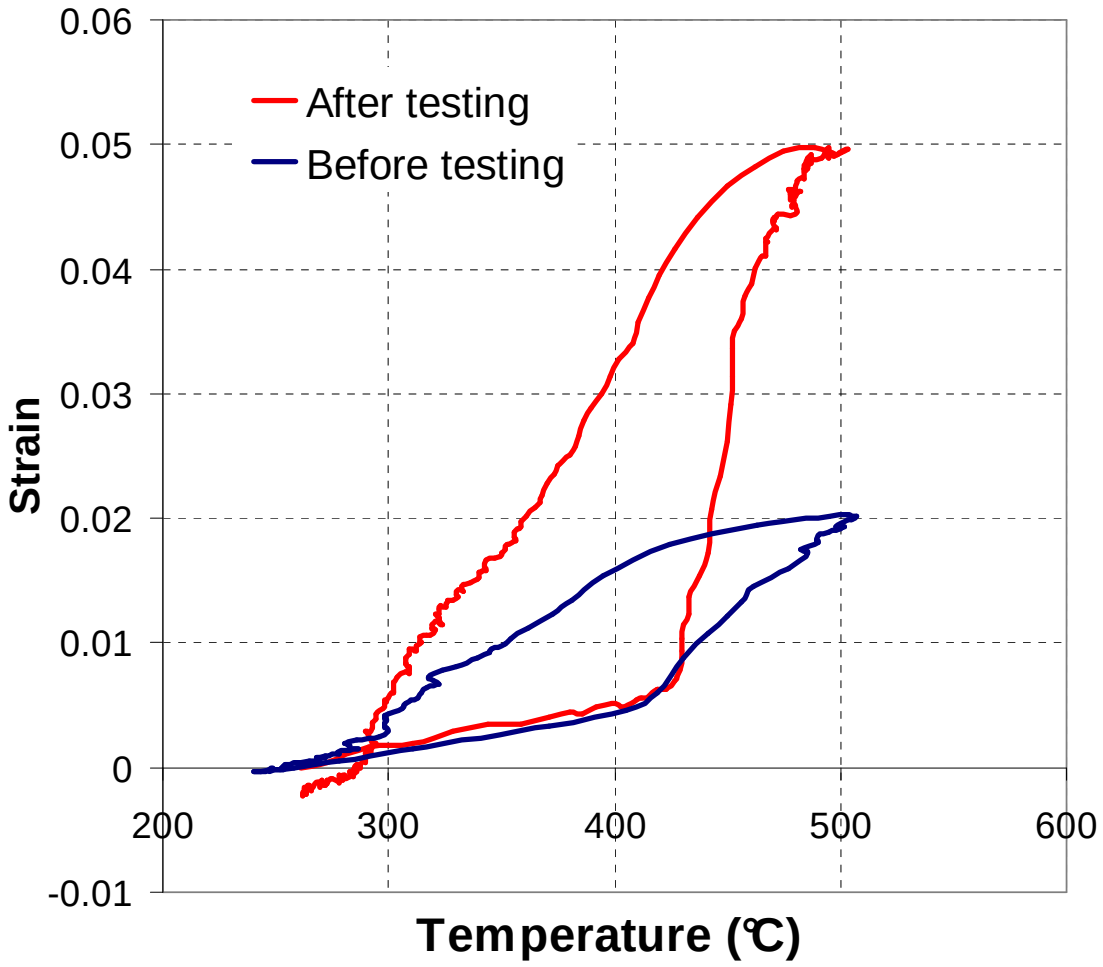
Isothermal unloading at 260℃



At 0 MPa

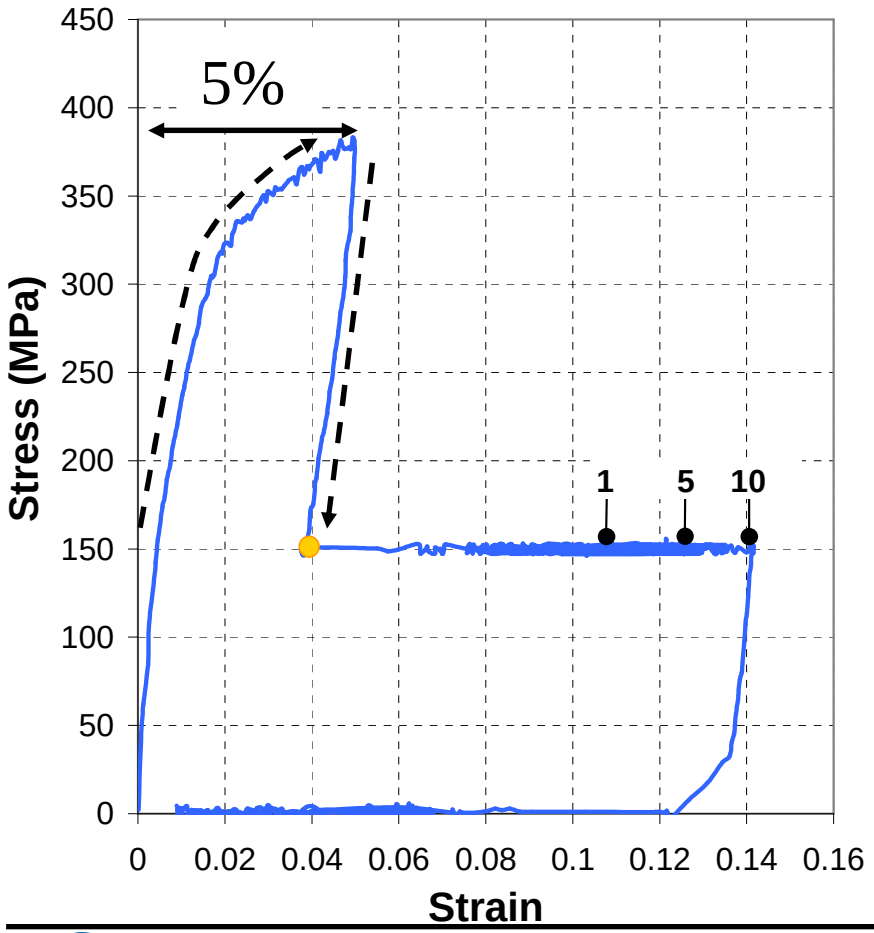


Compressive TWSME before and after testing

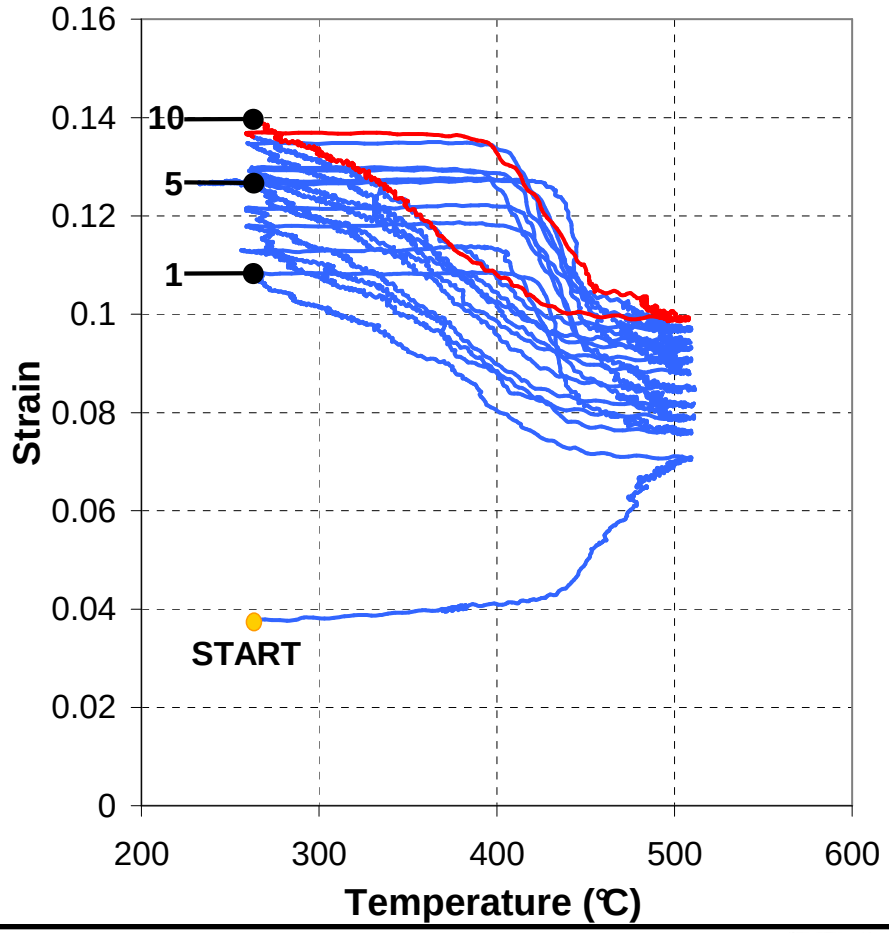


5% applied strain, thermal cycling under stress of 150 MPa

Isothermal loading at 260℃

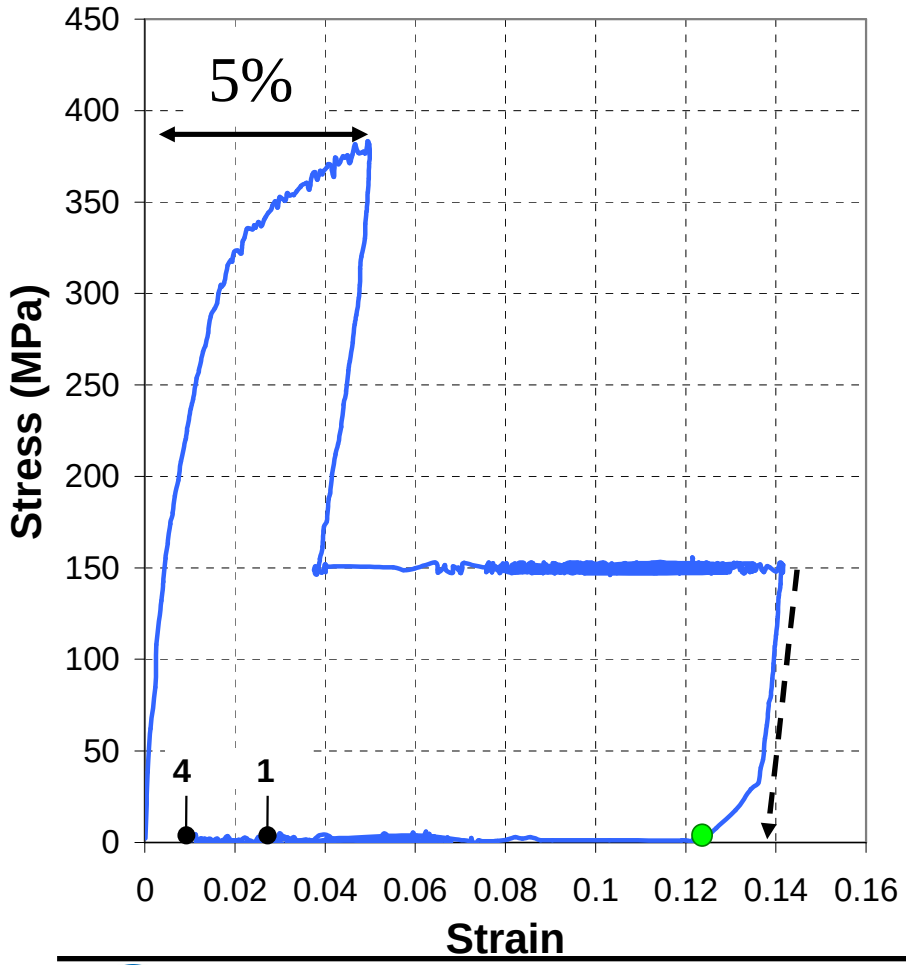


At 150 MPa

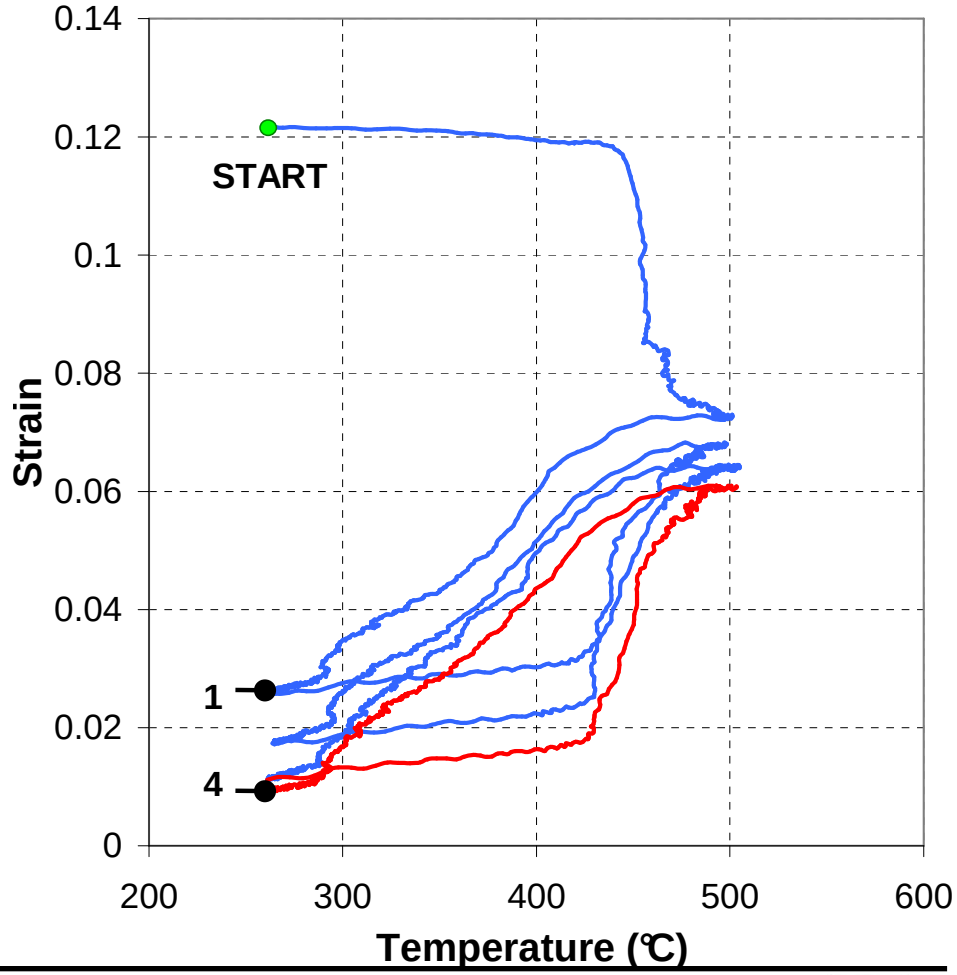


5% applied strain, thermal cycling under stress of 0 MPa

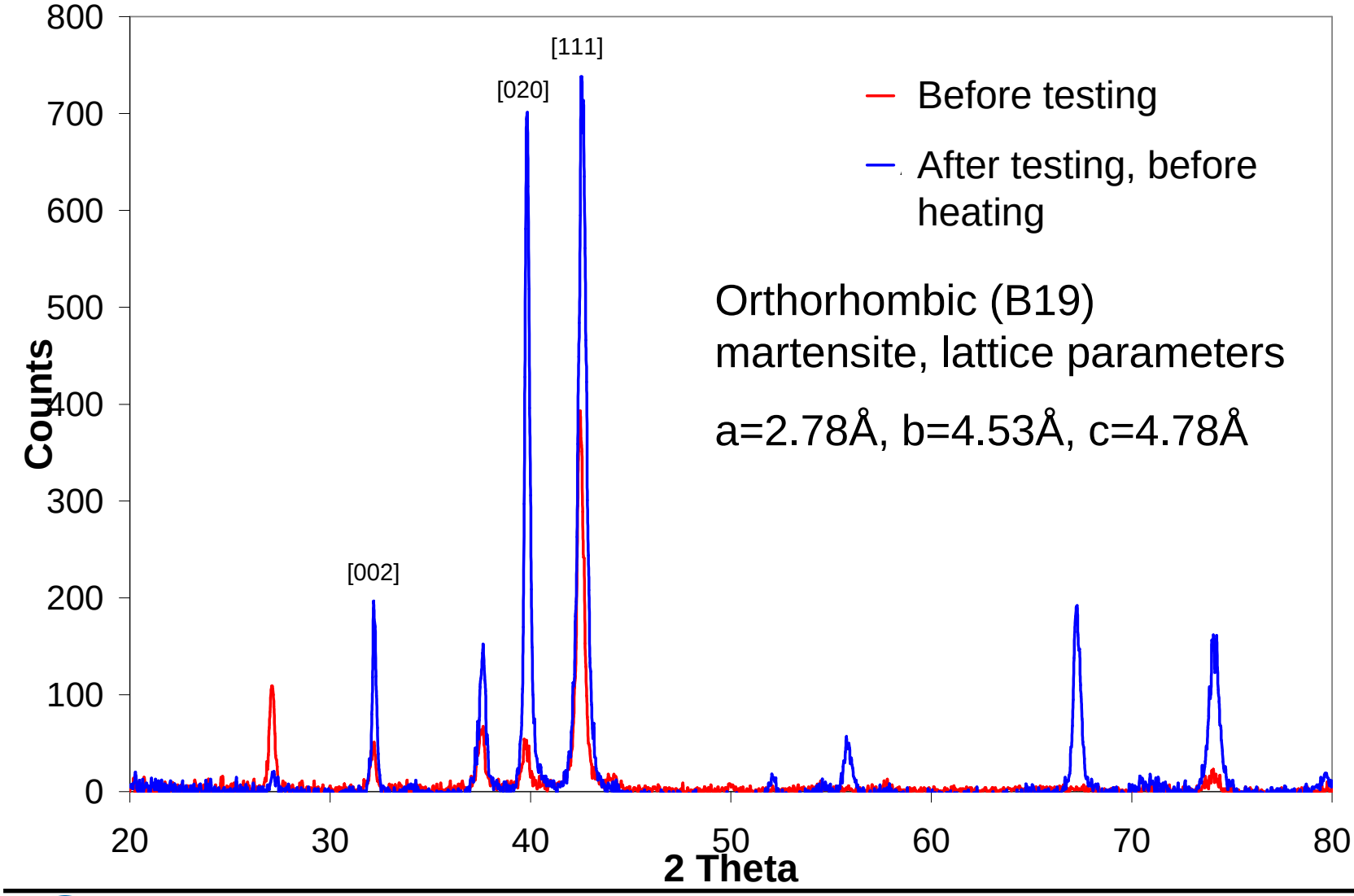
Isothermal unloading at 260℃



At 0 MPa



X-ray diffraction



Summary

- A dependence of recoverable transformation strain on the applied transformation is observed in the specimen.
- Low critical stress for slip under higher stress thermal cycling.
- Compression TWSME observed in the as fabricated material (after processing).
- Large transformation strains (≅ 7%) observed during the first transformation cycle under stress.
- The large transformation strain is recoverable in the absence of stress.

Future Work

- Improve the work characteristics by increasing the critical stress for slip of the material.
- Study the nature of the strong biasing force resulting in the unique transformation behavior.
- Study the stability of this unique behavior under cyclic actuation.

Thermal cycling of as received specimen under zero stress