

The Effect of Low Temperature Aging on Ni-Rich Ti-Ni

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Outline:

- Annealed Ni-rich Ti-Ni

Aging temperatures: 100°C - 200°C & exposure times up to 720 hours (one month)

- Thermal properties (DSC results)
- Microstructural changes

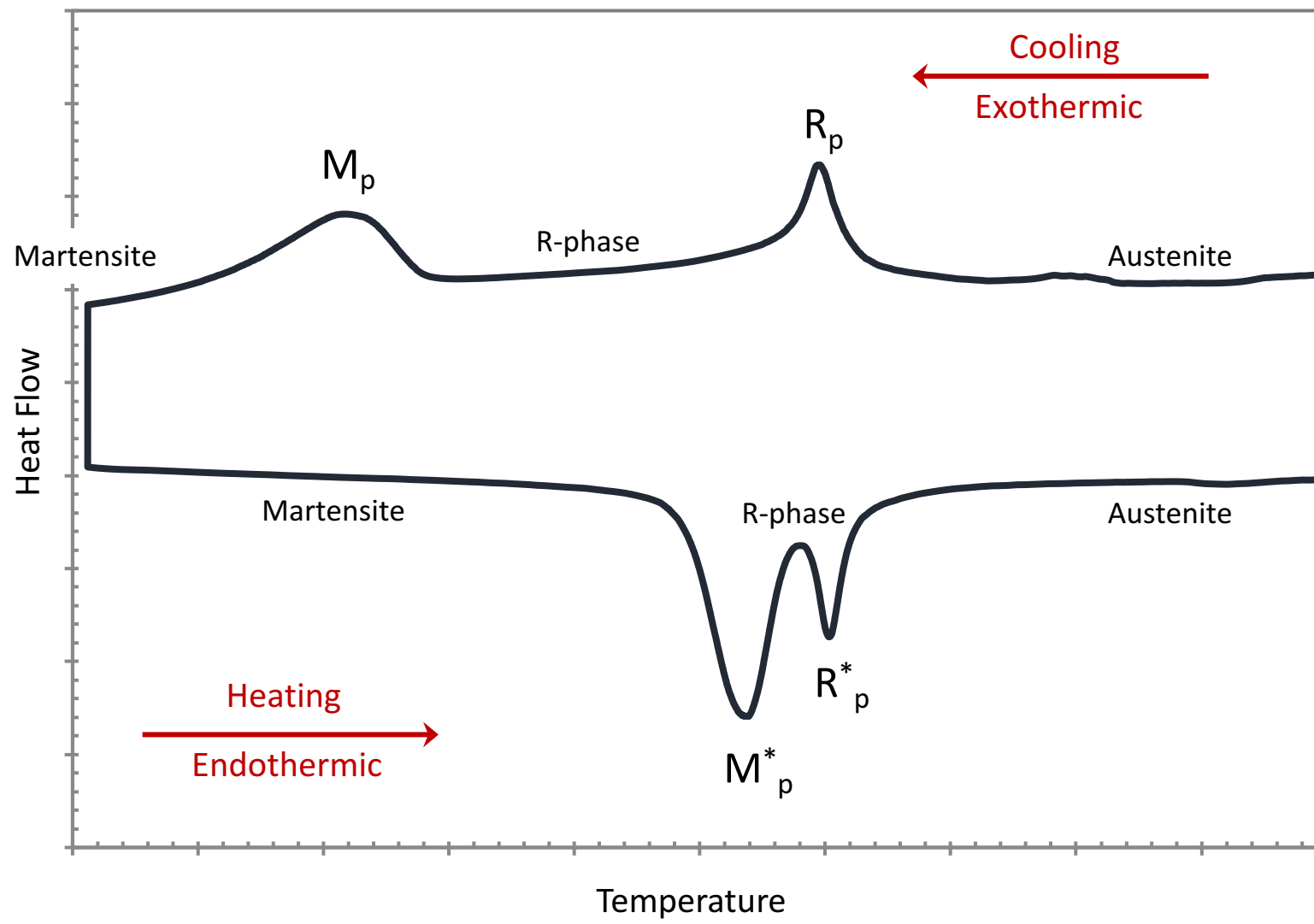
- Cold-Worked and Heat Treated Ni-rich Ti-Ni

Aging temperatures: 100°C - 250°C & exposure times up to 720 hours (one month)

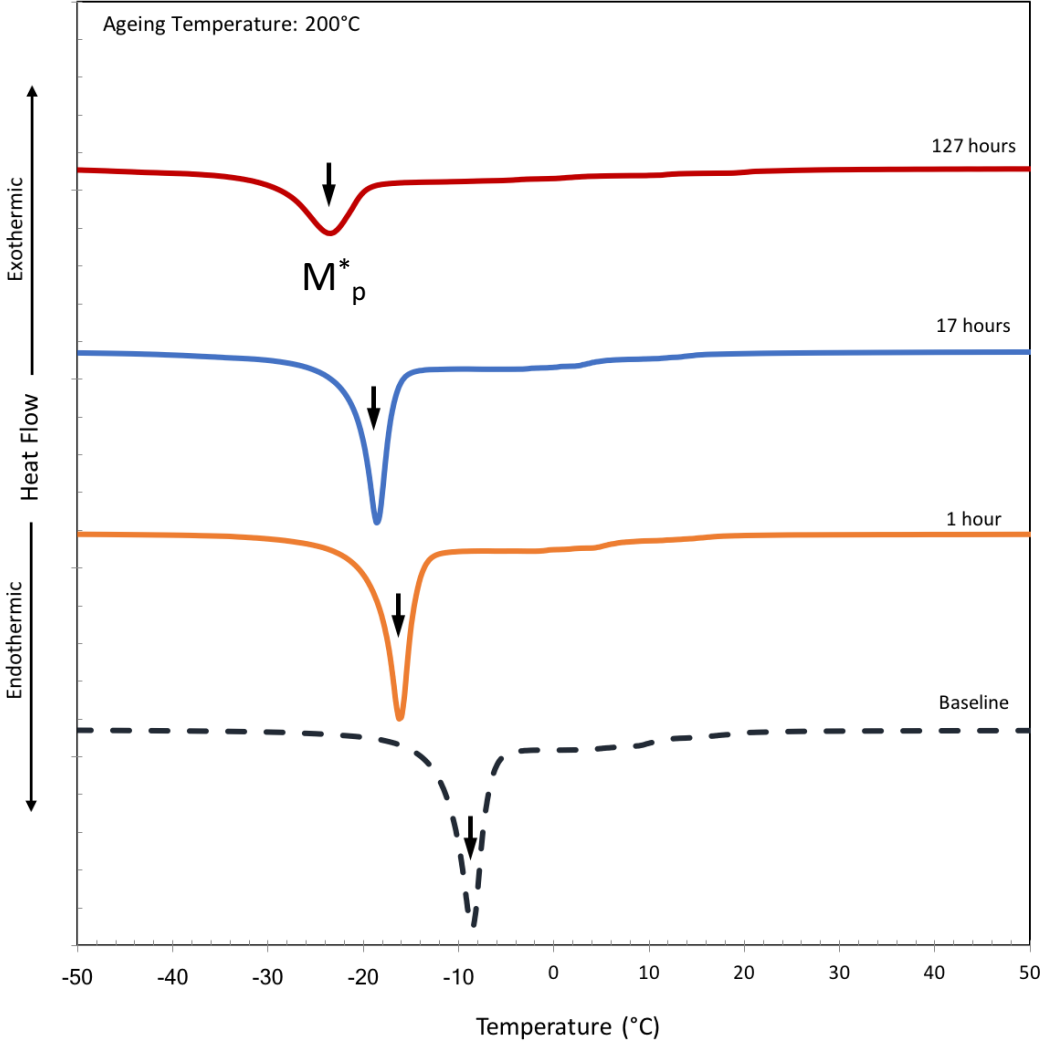
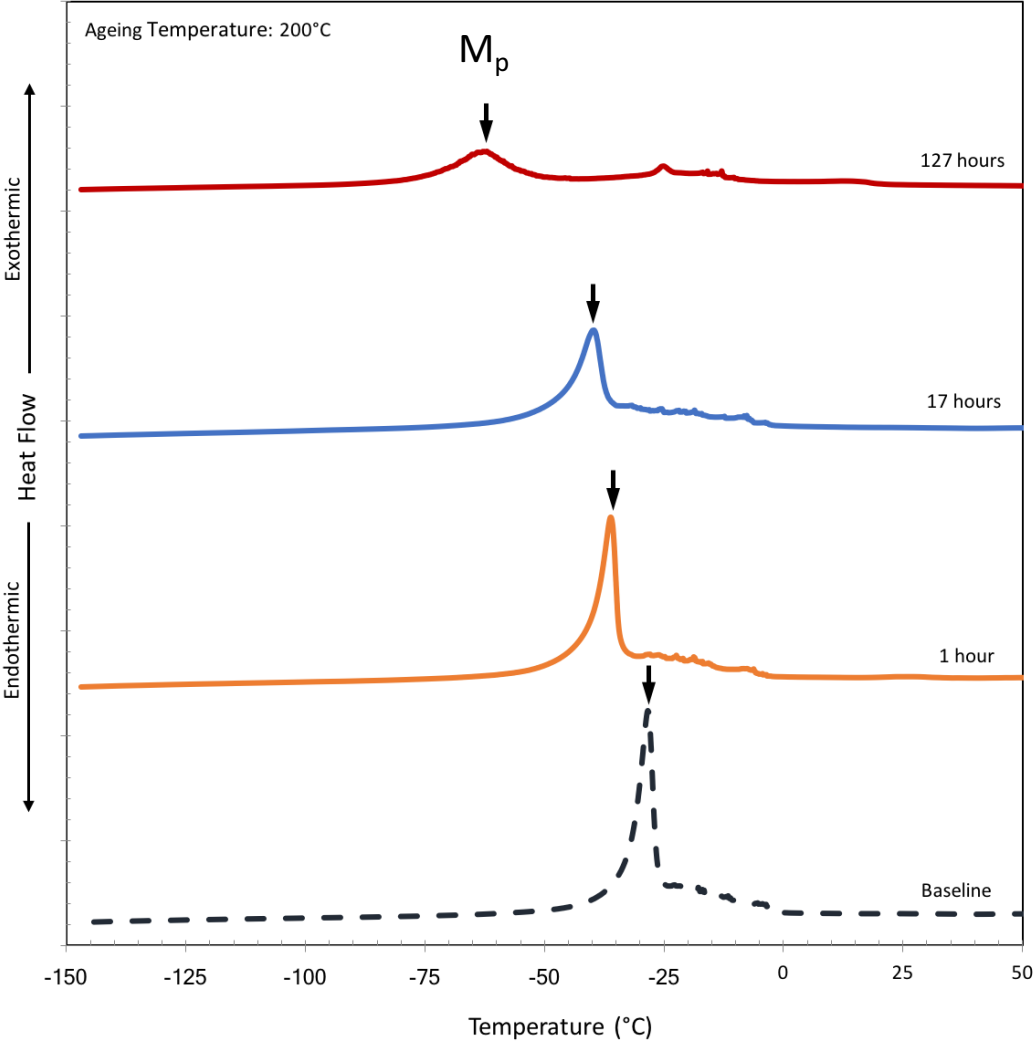
- Thermal properties (DSC results)
- Influence on mechanical properties

- Remarks & Conclusions

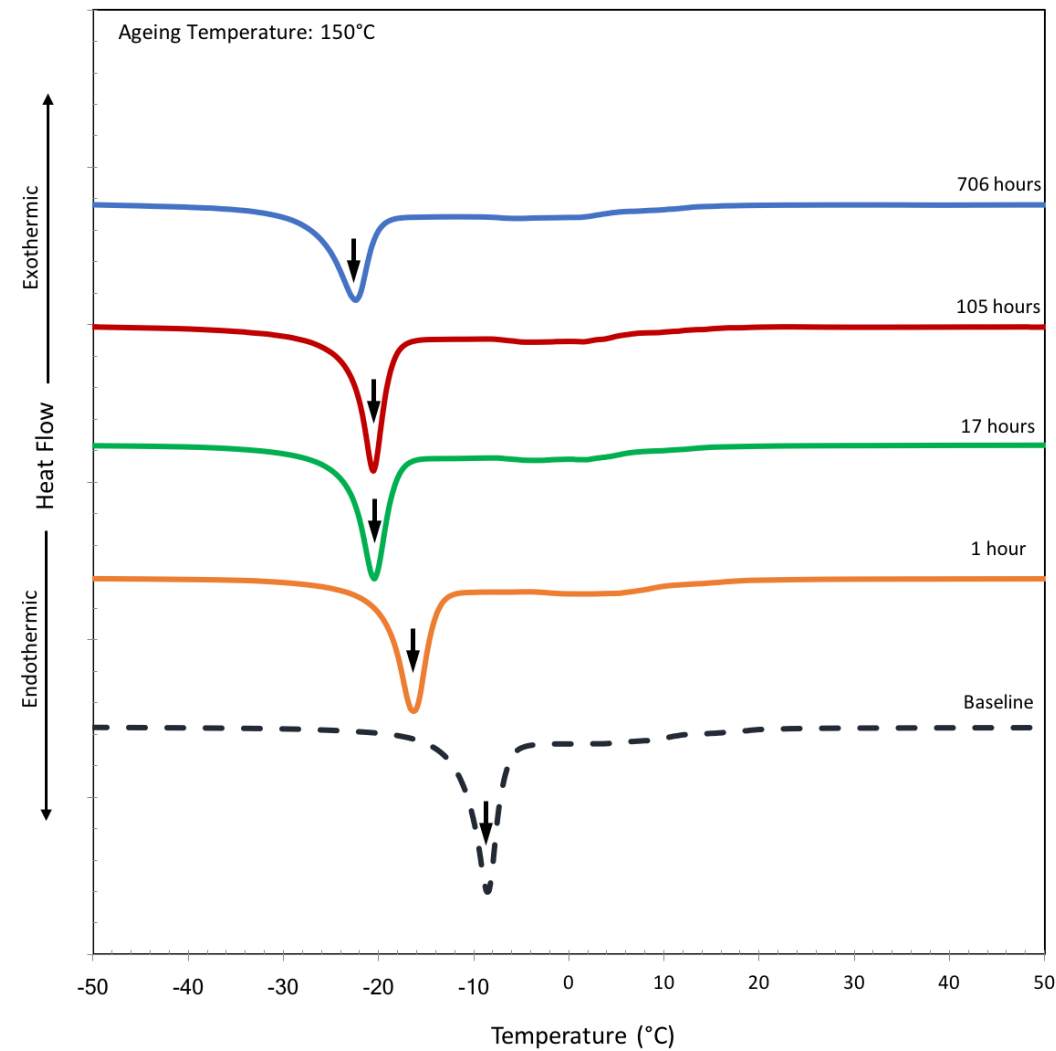
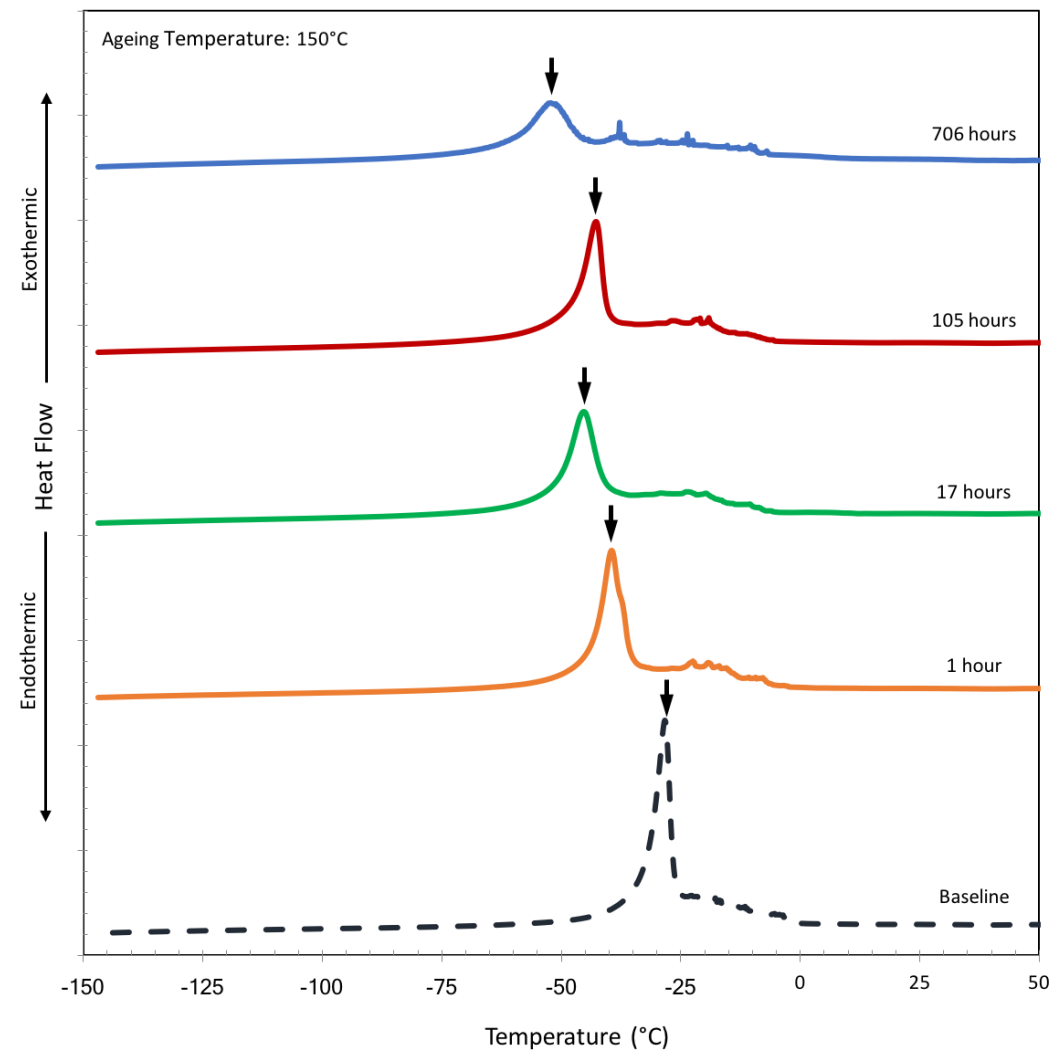
DSC Graph – Terminology



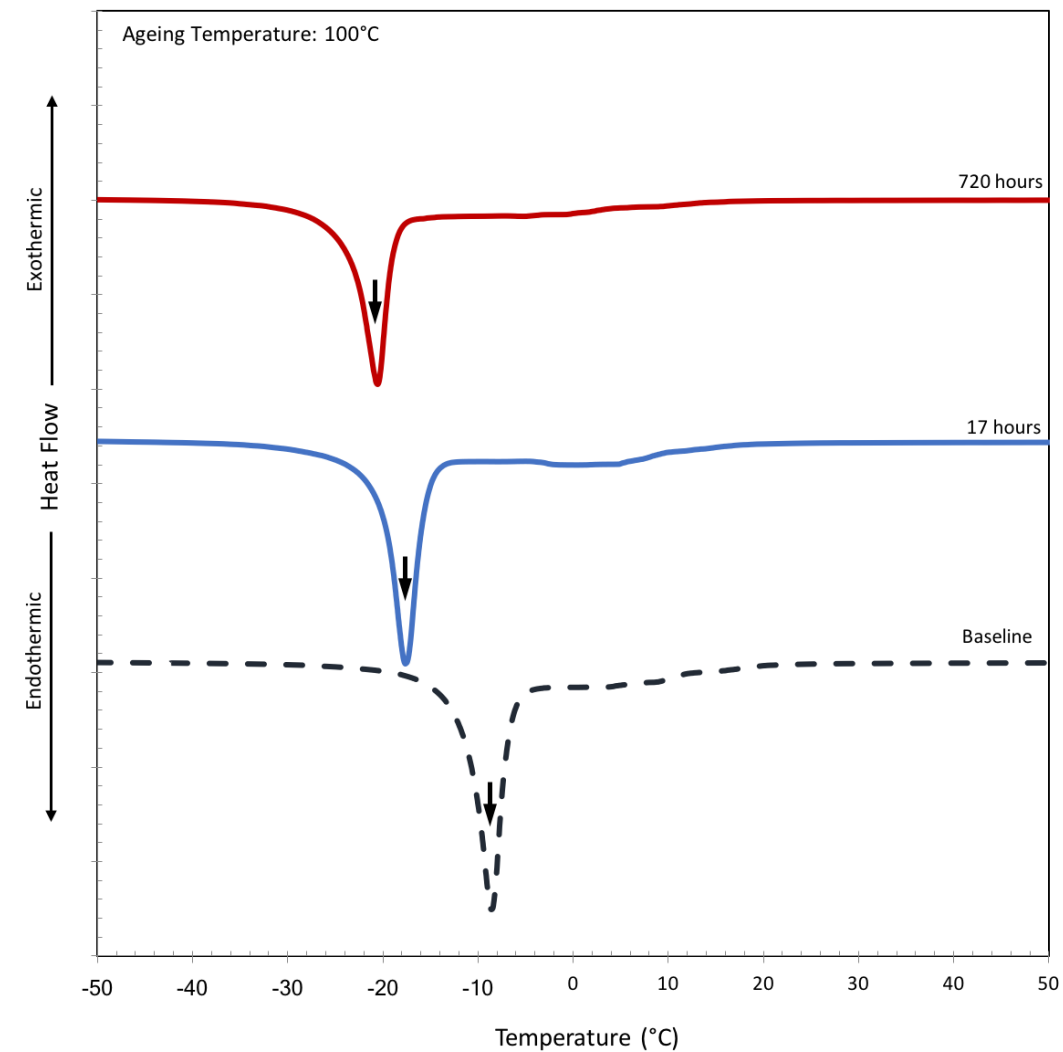
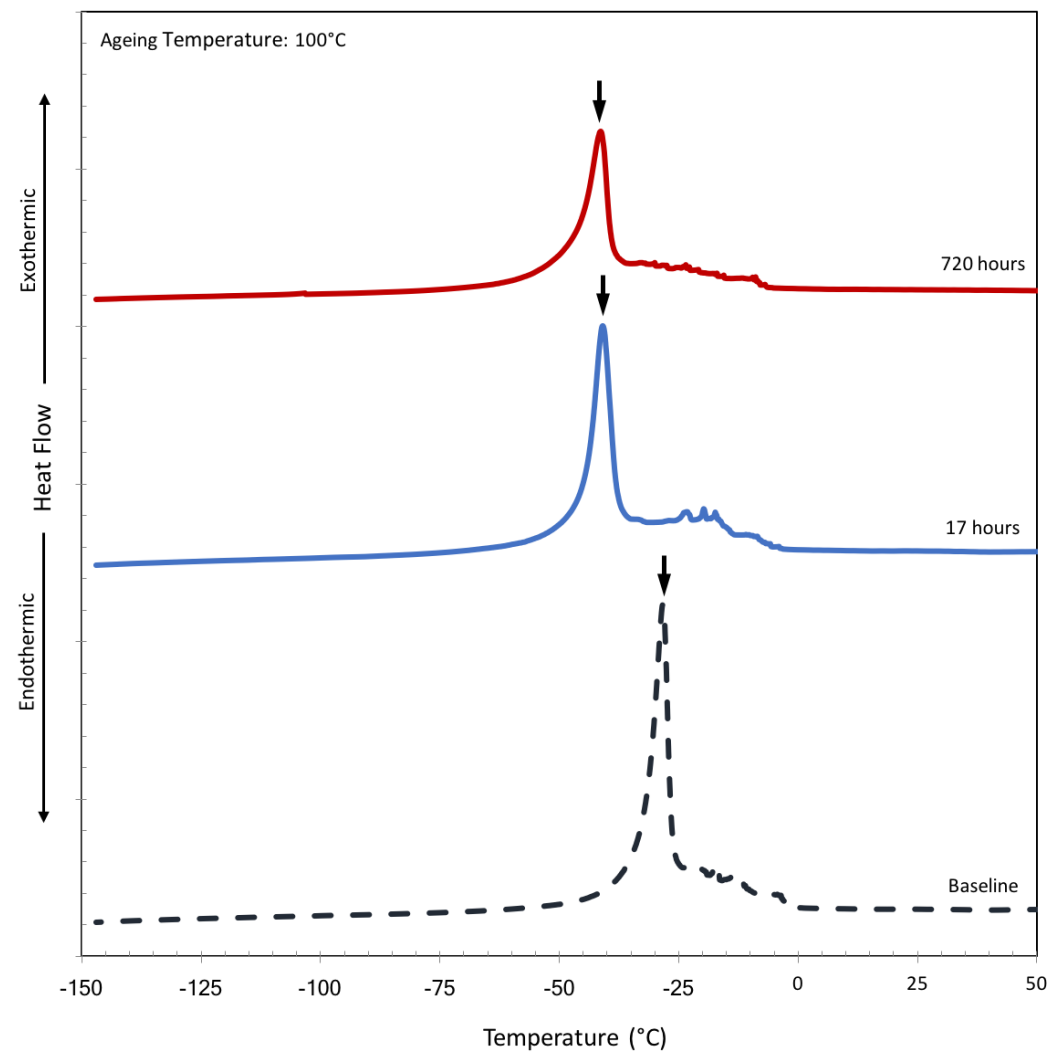
Fully Annealed Sample – Aged at 200°C



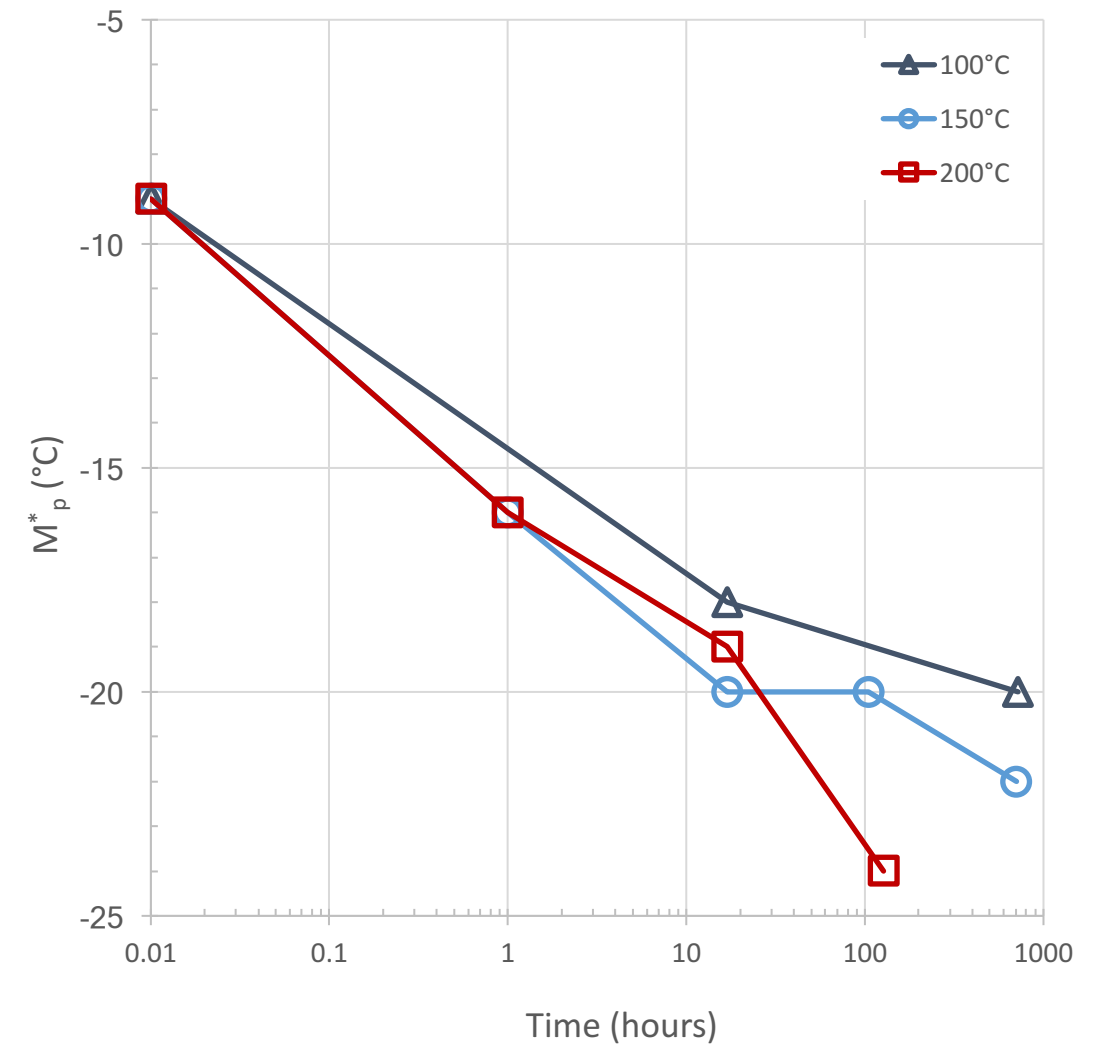
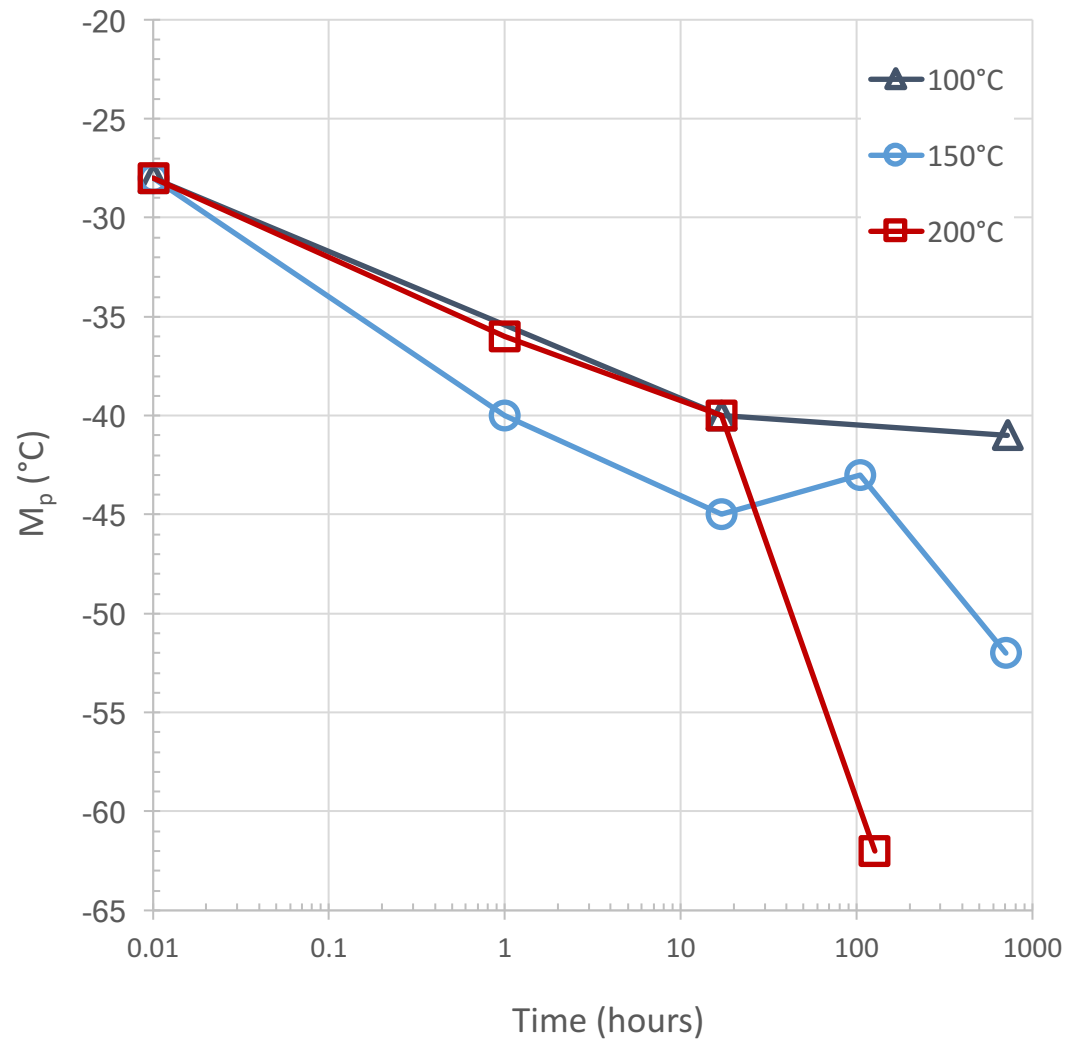
Fully Annealed Sample – Aged at 150°C



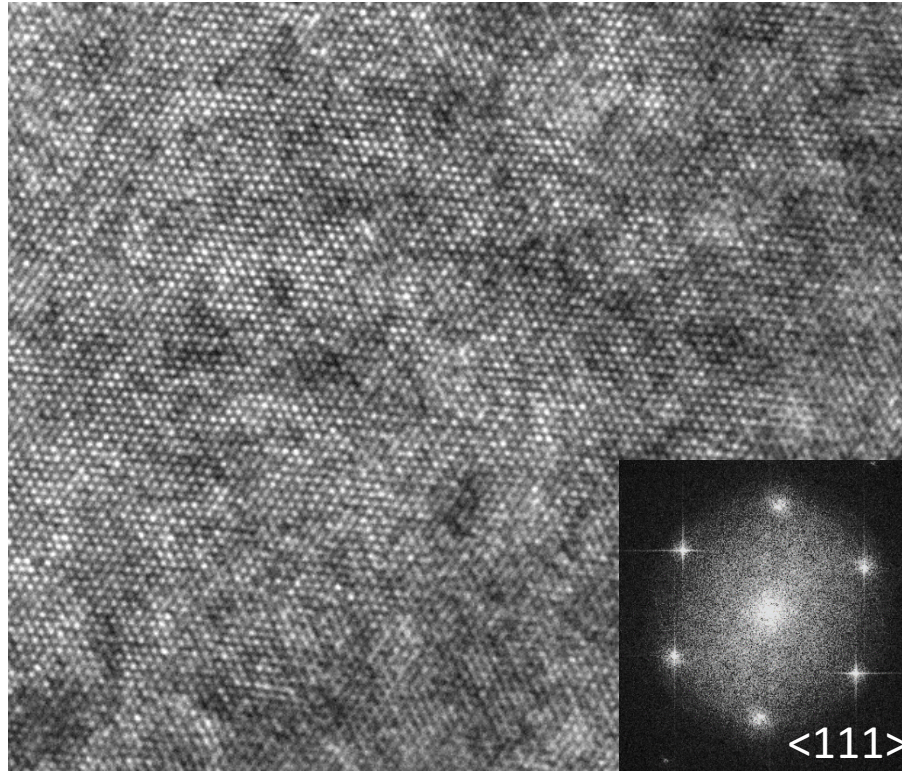
Fully Annealed Sample – Aged at 100°C



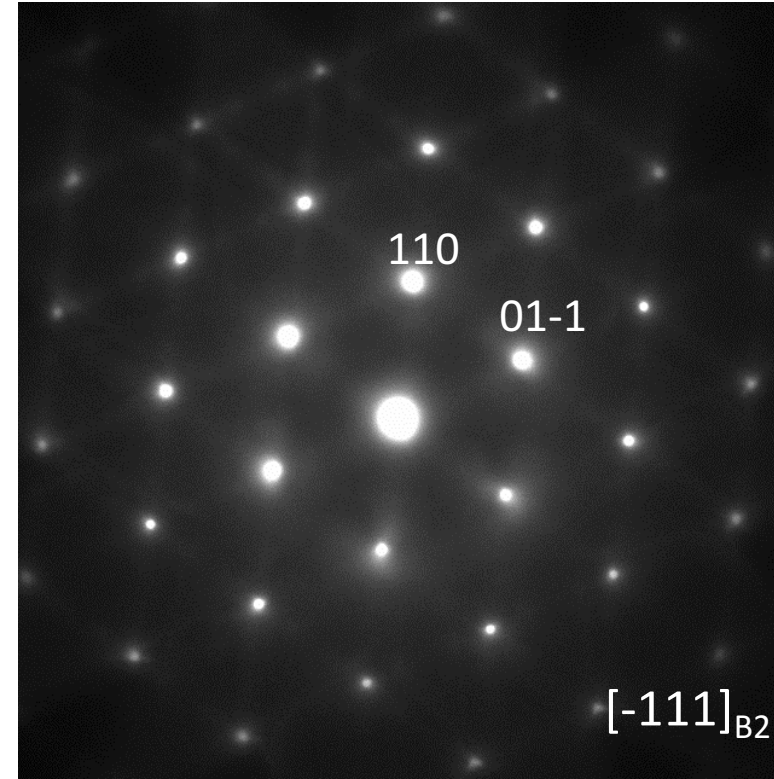
Suppression of Martensite Formation (M_p) and Reversion (M_p^*)



Fully Annealed Sample – Baseline



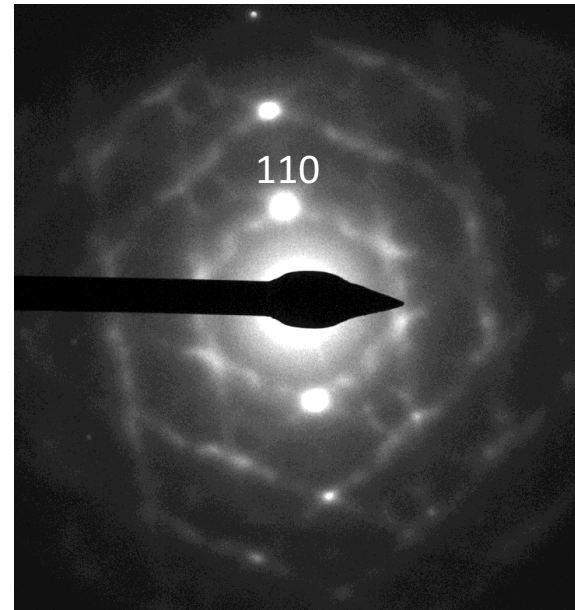
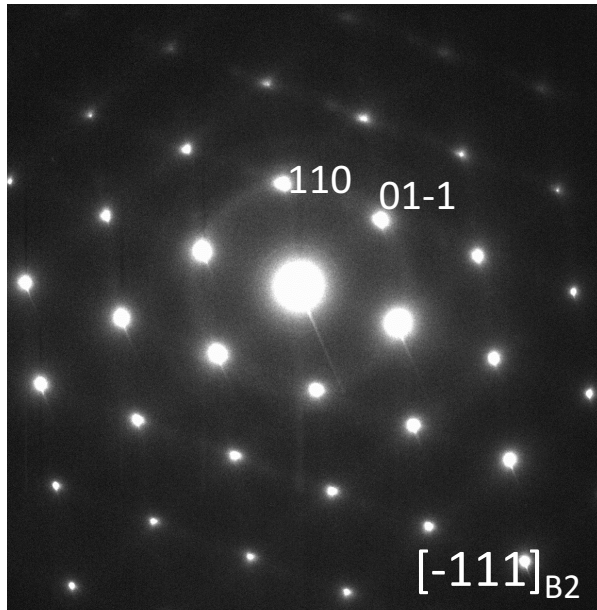
High resolution TEM micrograph along
 $\langle 111 \rangle$ direction



Selected area diffraction pattern

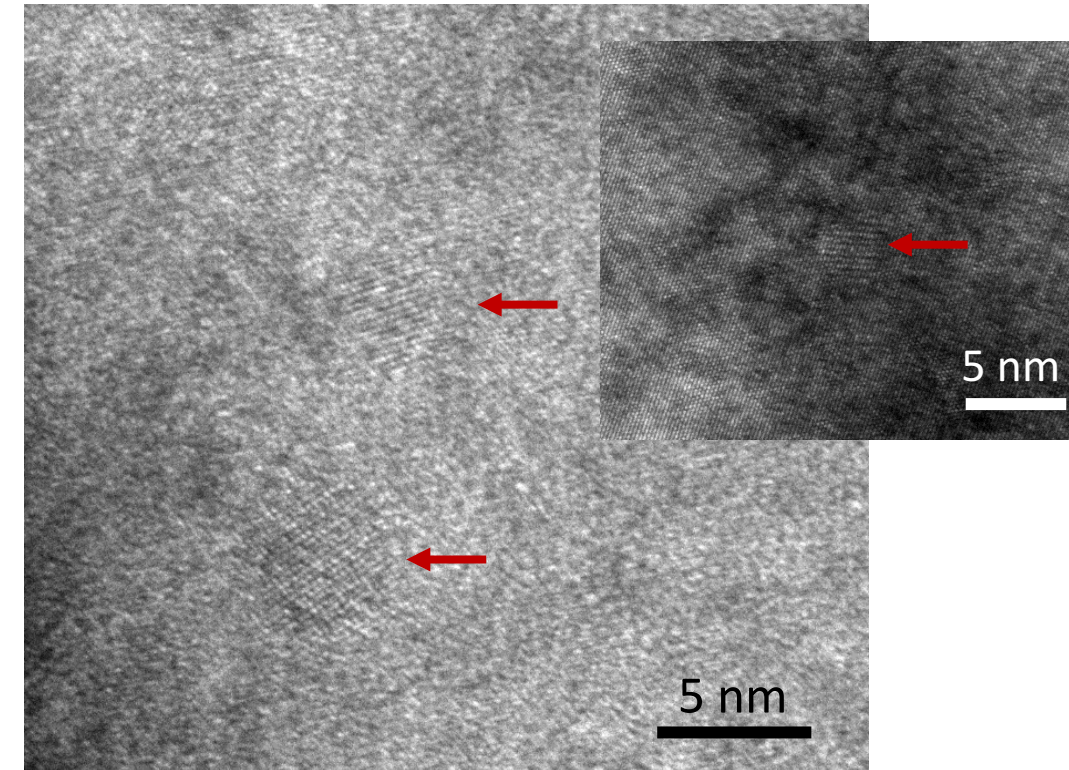
- No Evidence of Precipitation

Fully Annealed Sample – Aged at 100°C for 105 hours



Tilting the sample around $[110]$ direction and diffuse intensities (evidence of Ni clustering) are appeared in diffraction pattern.

- Evidence of Ni Clustering (Precursor to Precipitation)*
- Evidence of Precipitation



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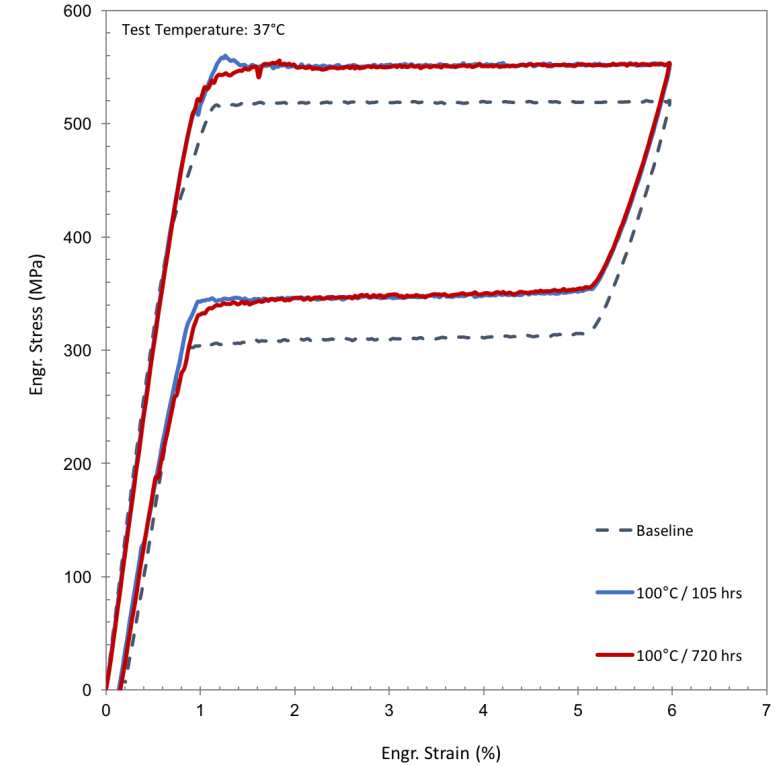
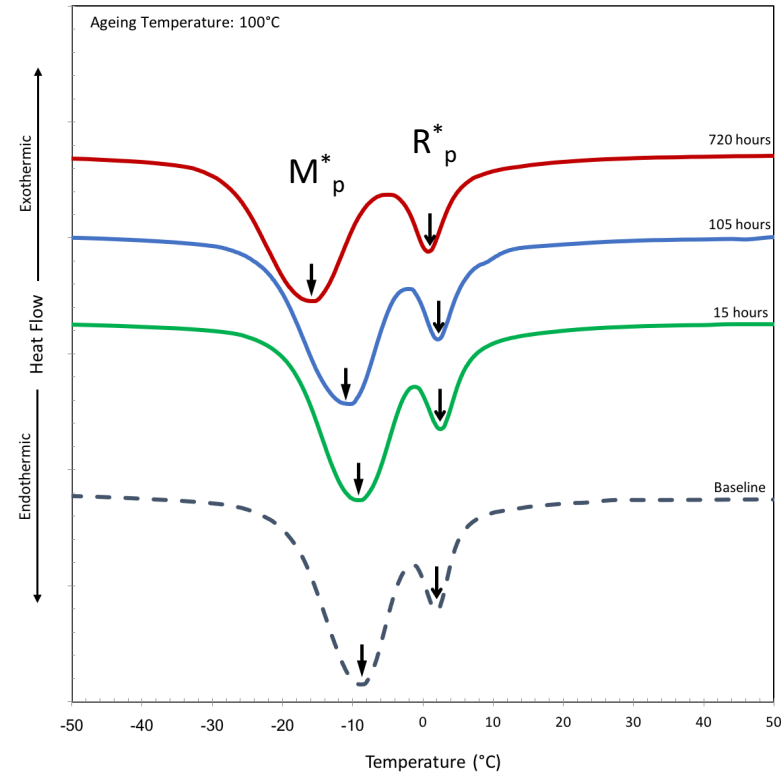
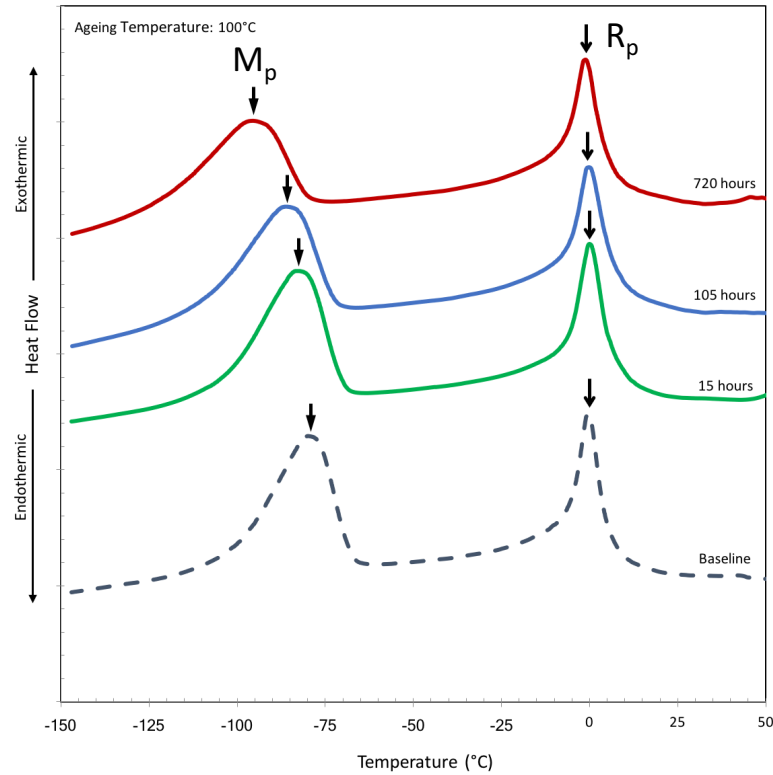
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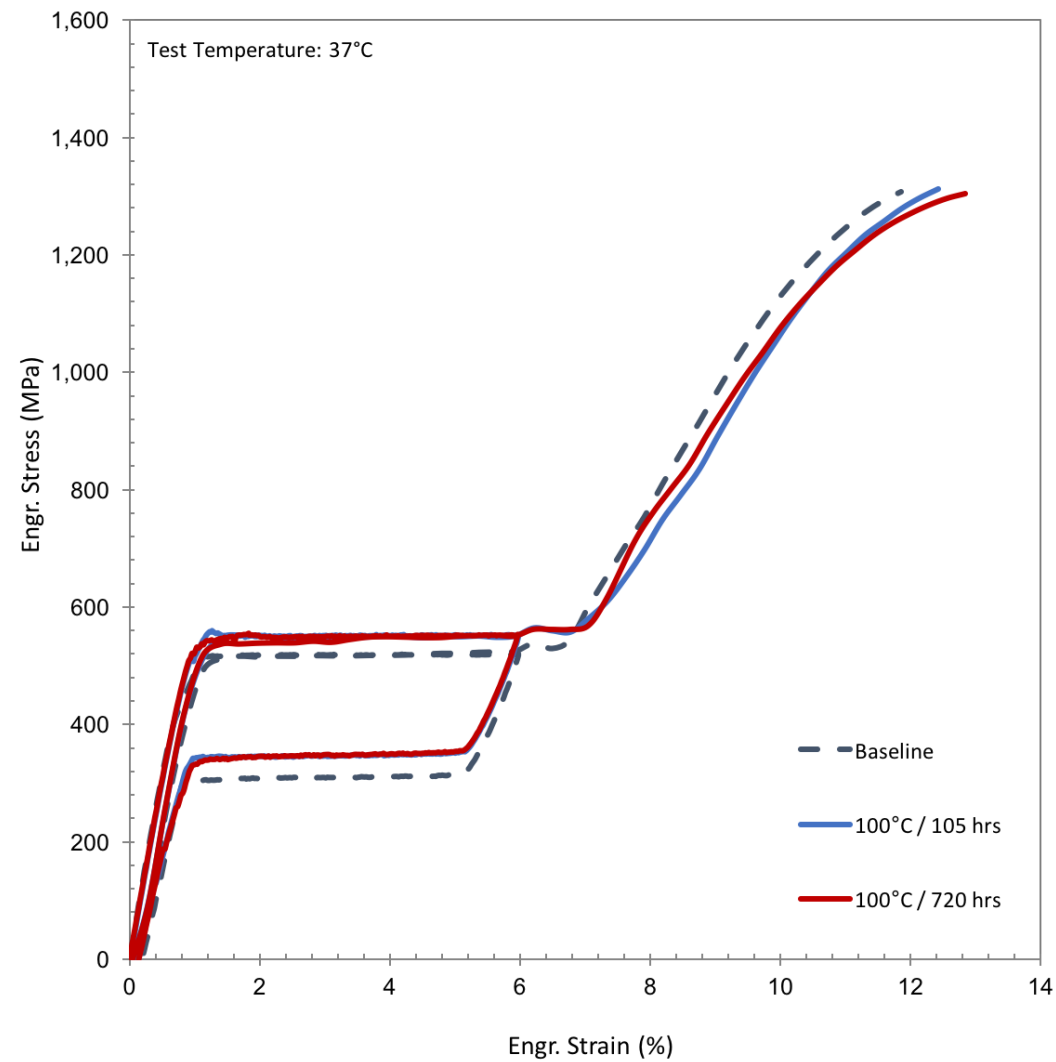
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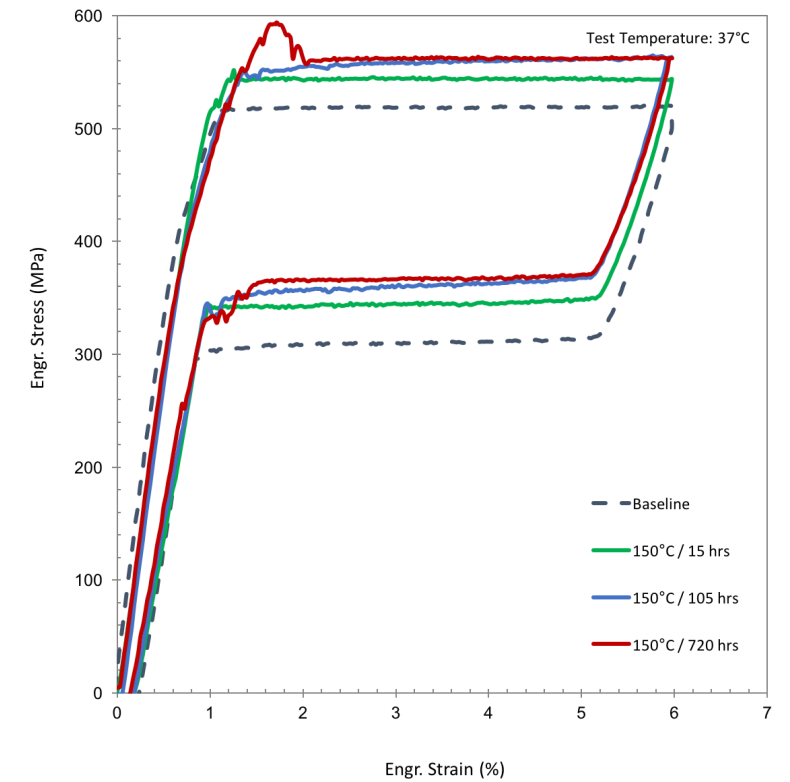
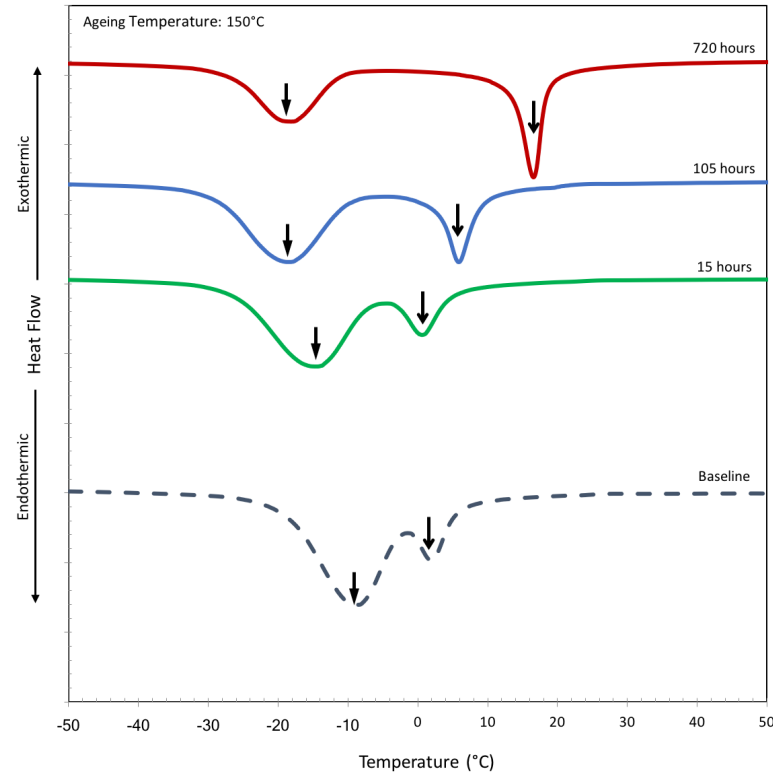
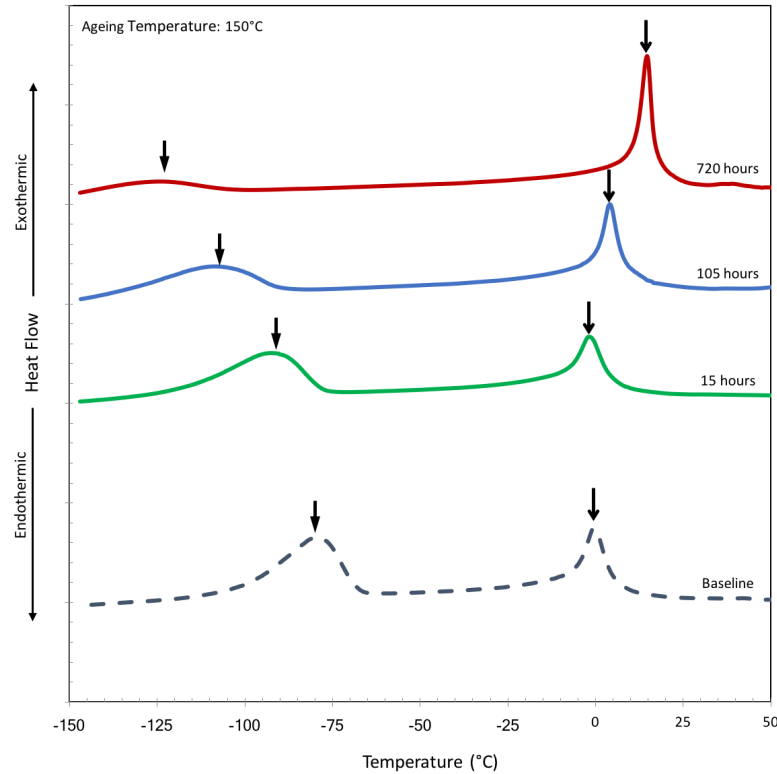
Sample with Retained CW & Precipitates – Aged at 100°C



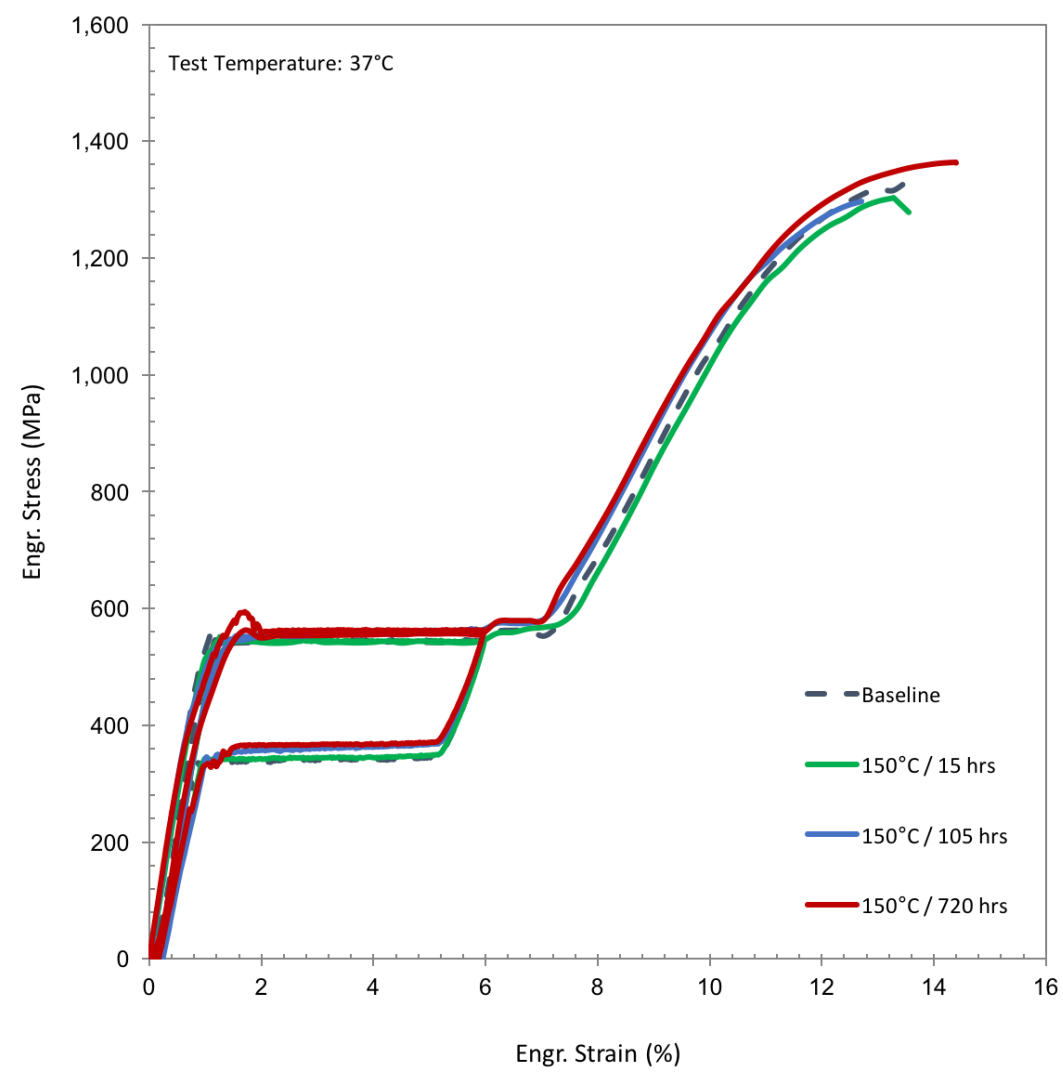
Sample with Retained CW & Precipitates – Aged at 100°C



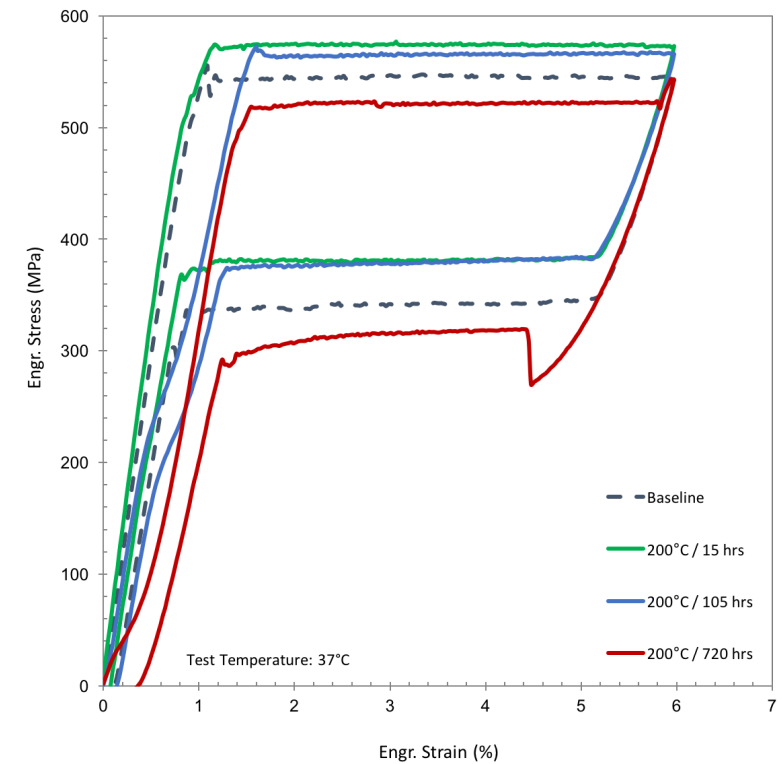
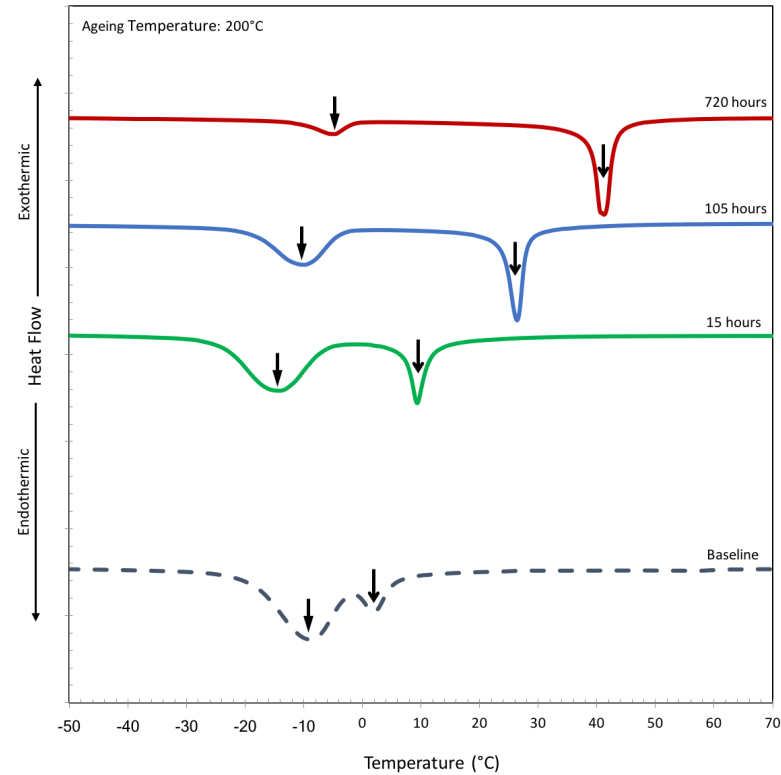
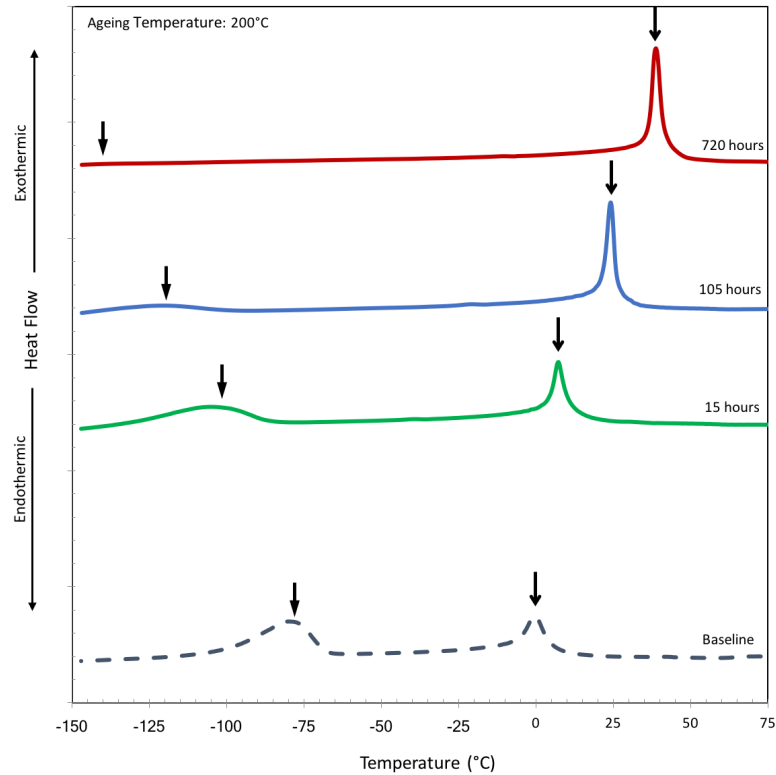
Sample with Retained CW & Precipitates – Aged at 150°C



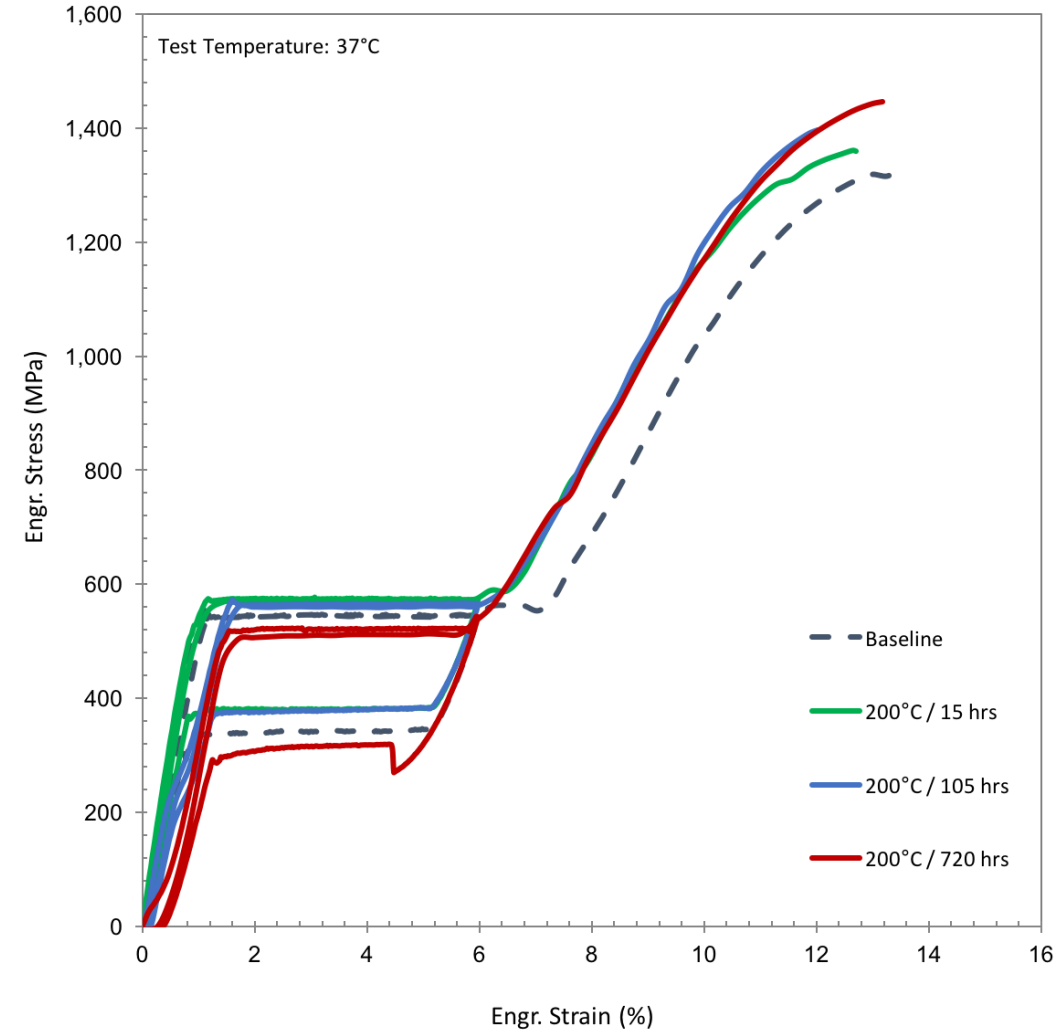
Sample with Retained CW & Precipitates – Aged at 150°C



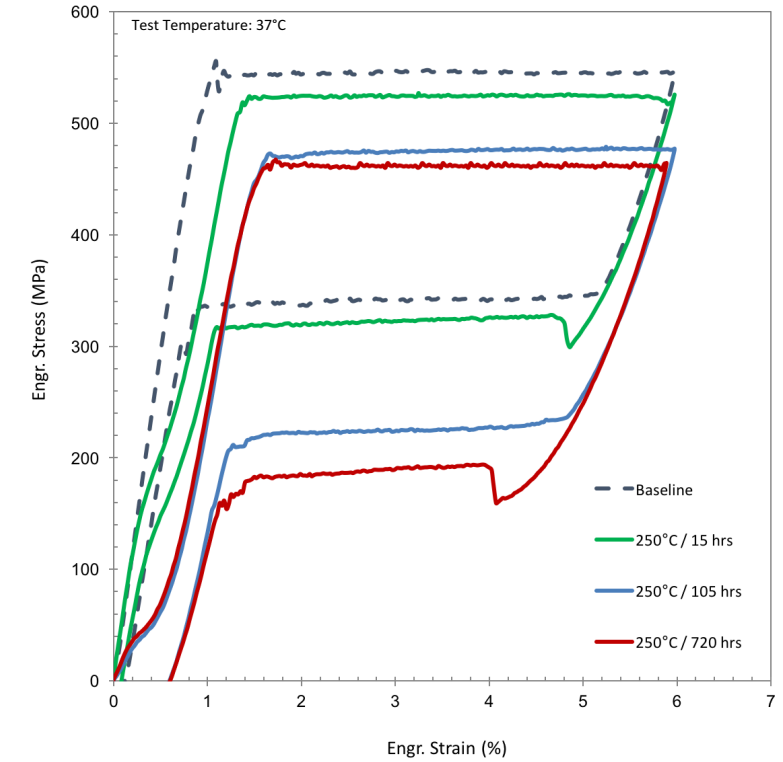
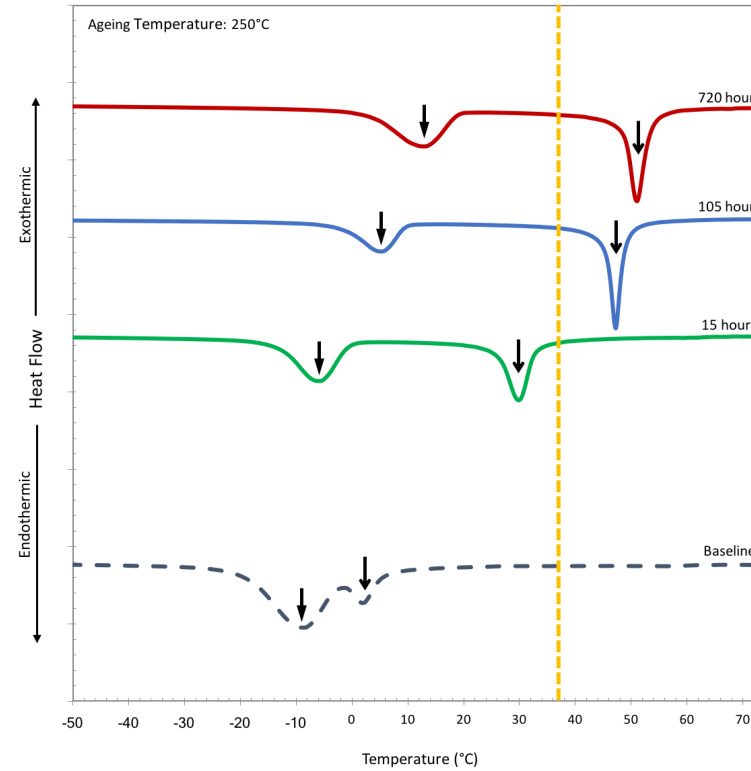
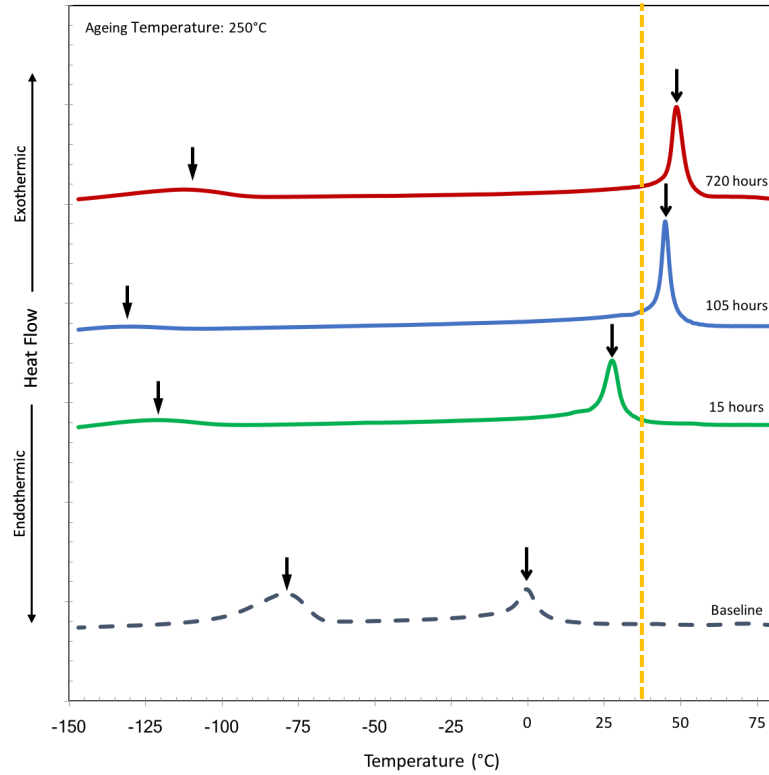
Sample with Retained CW & Precipitates – Aged at 200°C



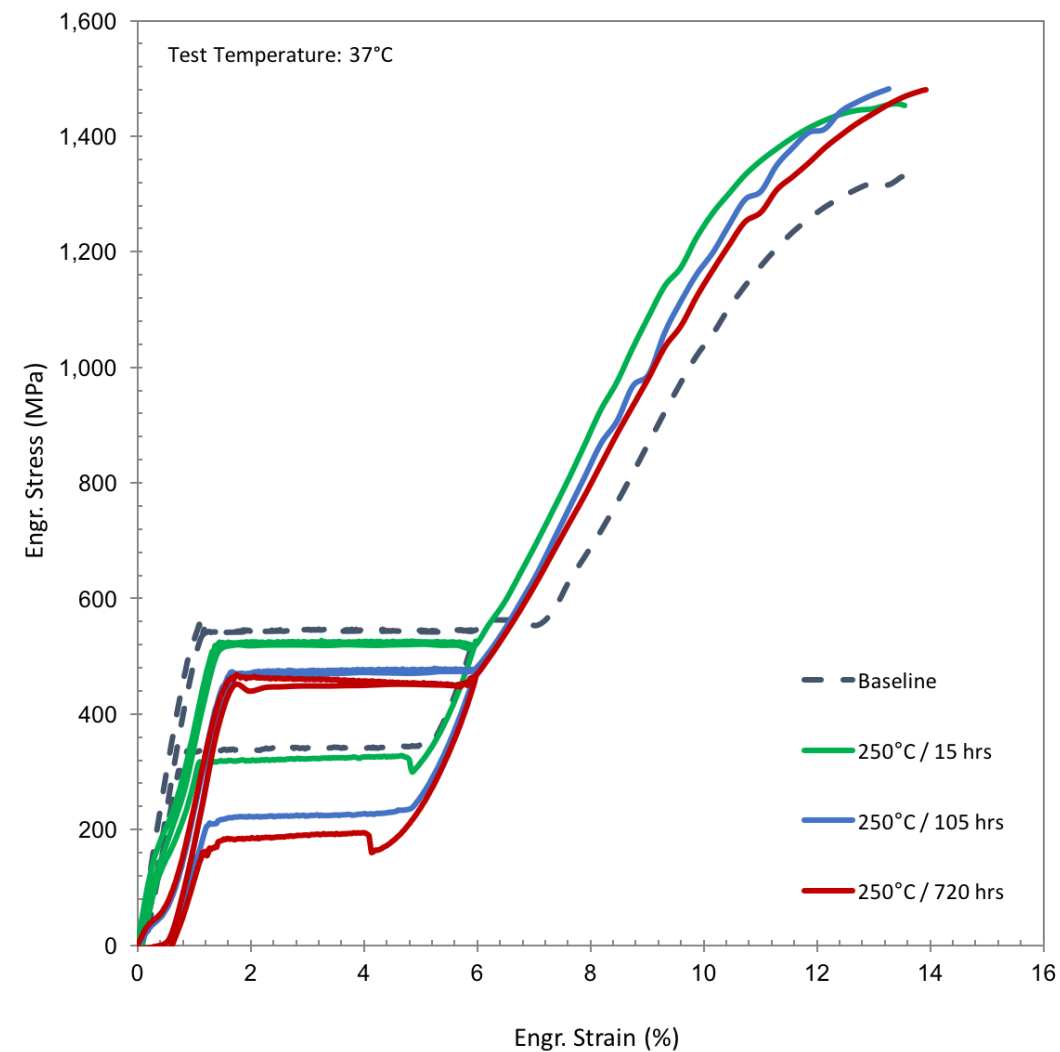
Sample with Retained CW & Precipitates – Aged at 200°C



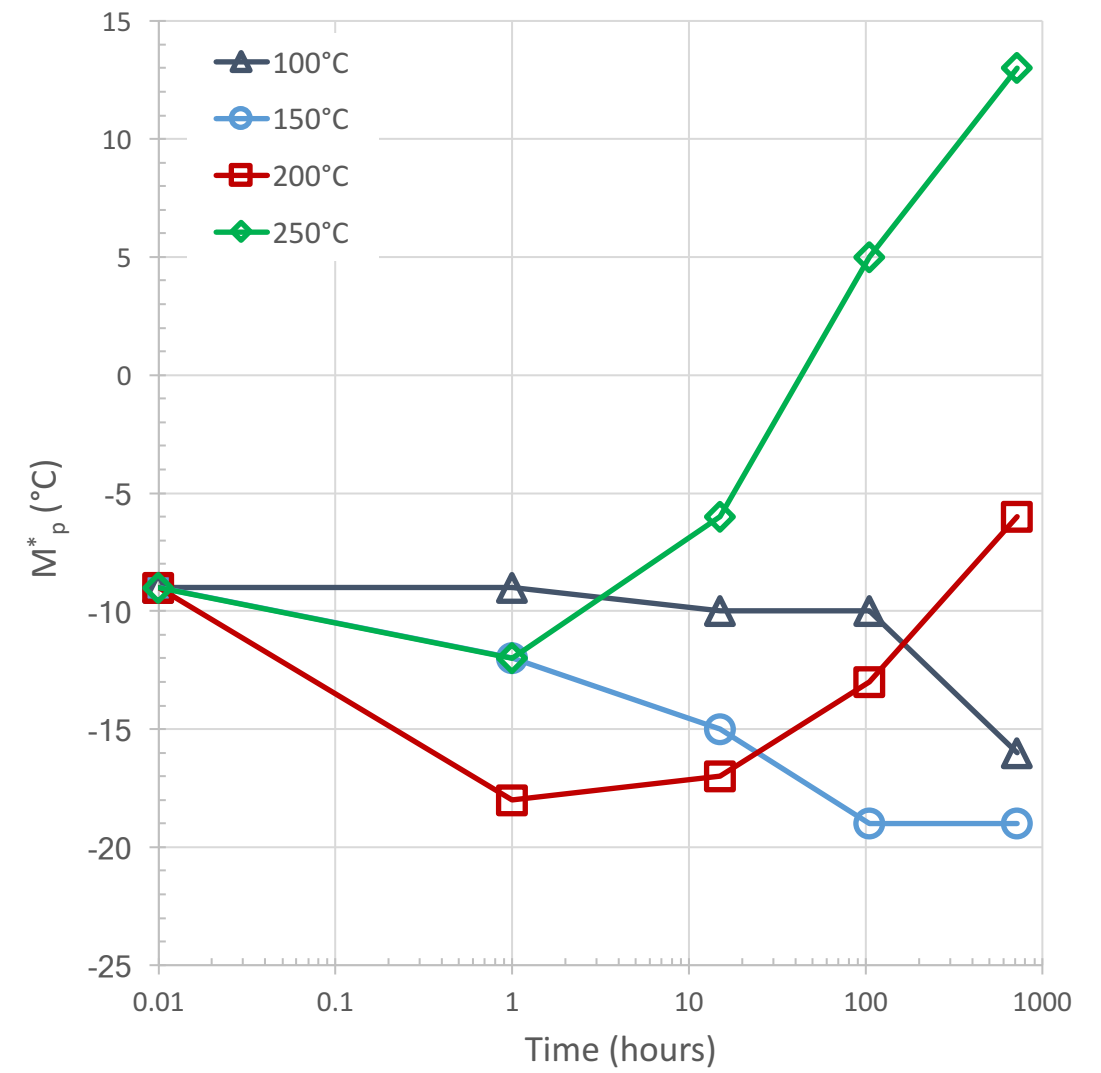
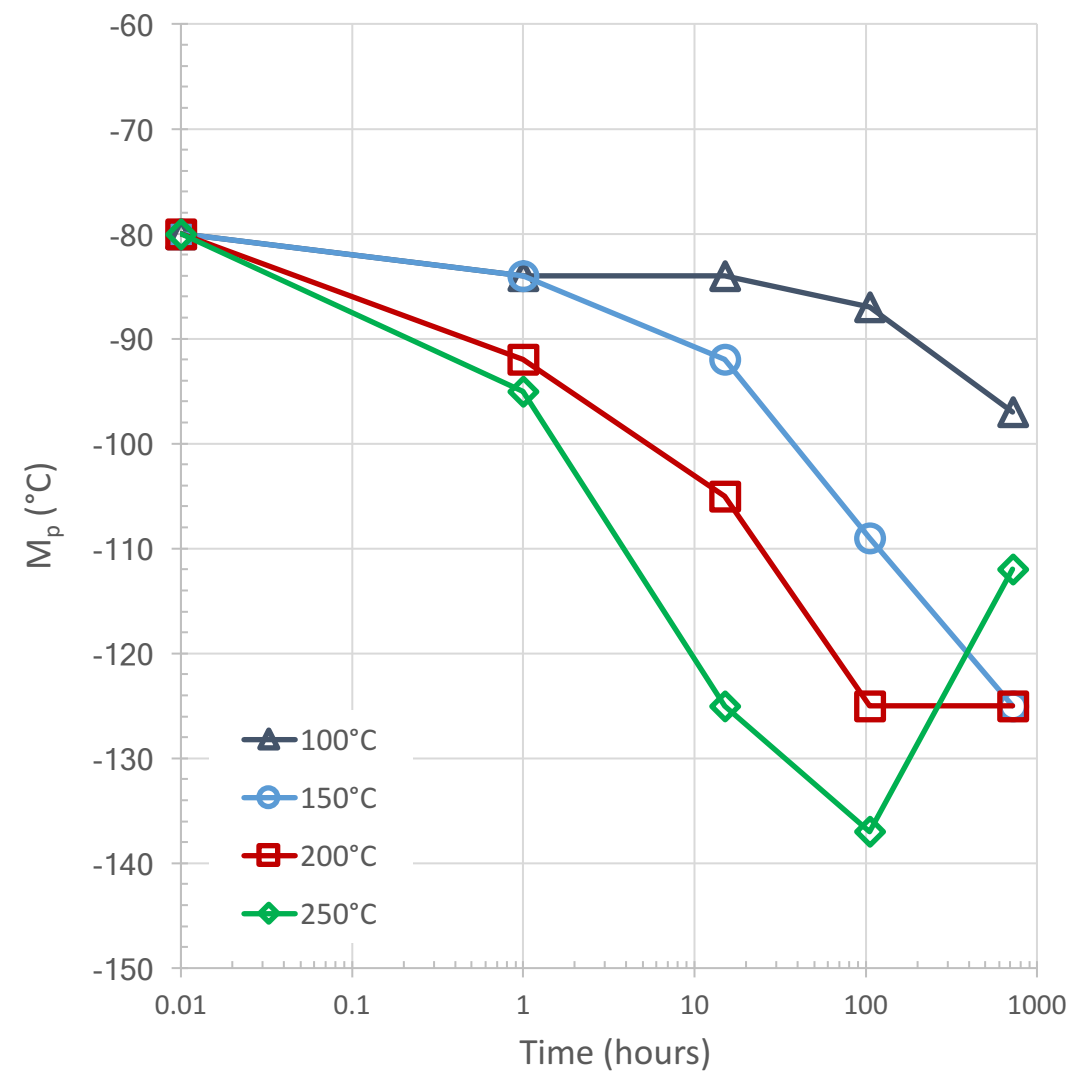
Sample with Retained CW & Precipitates – Aged at 250°C



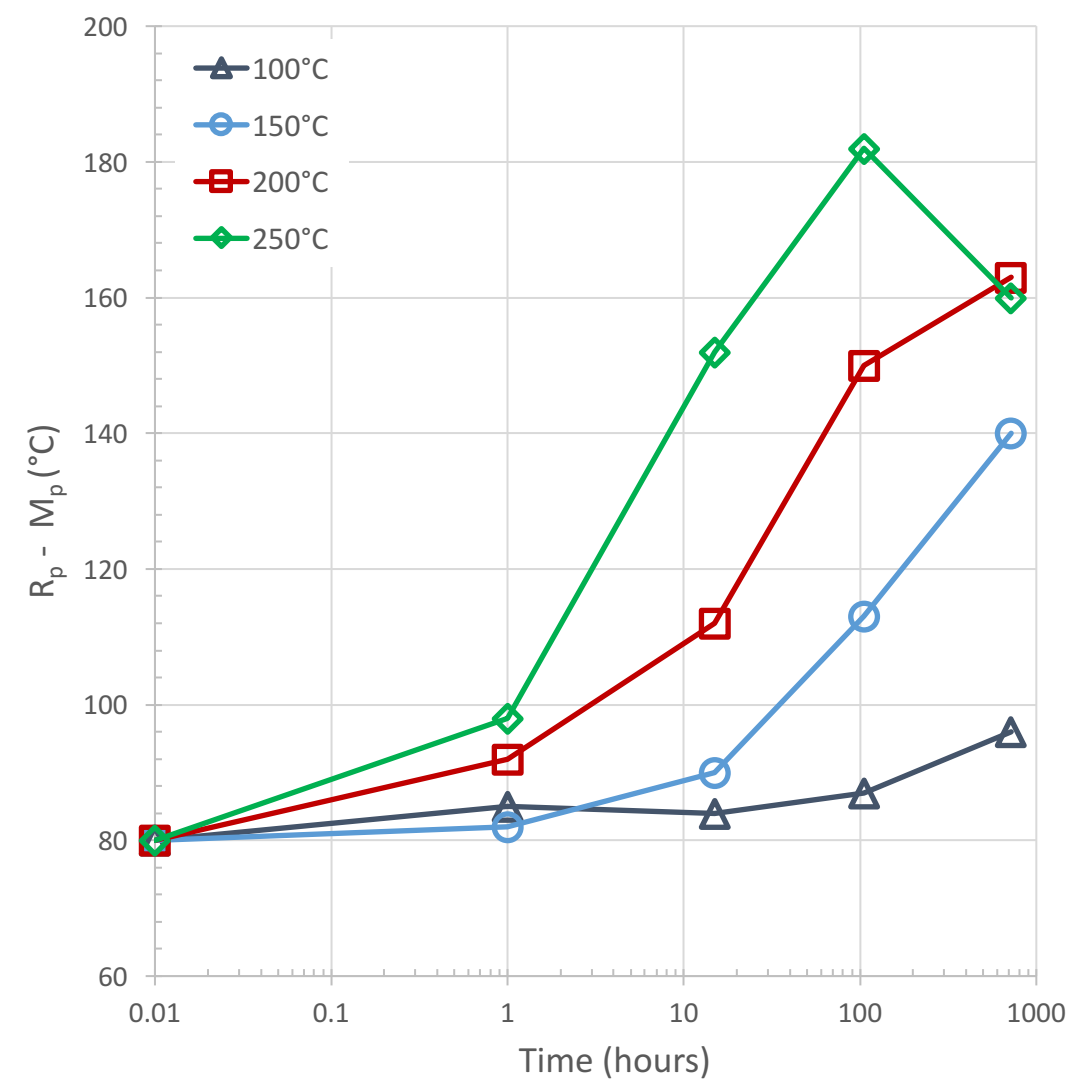
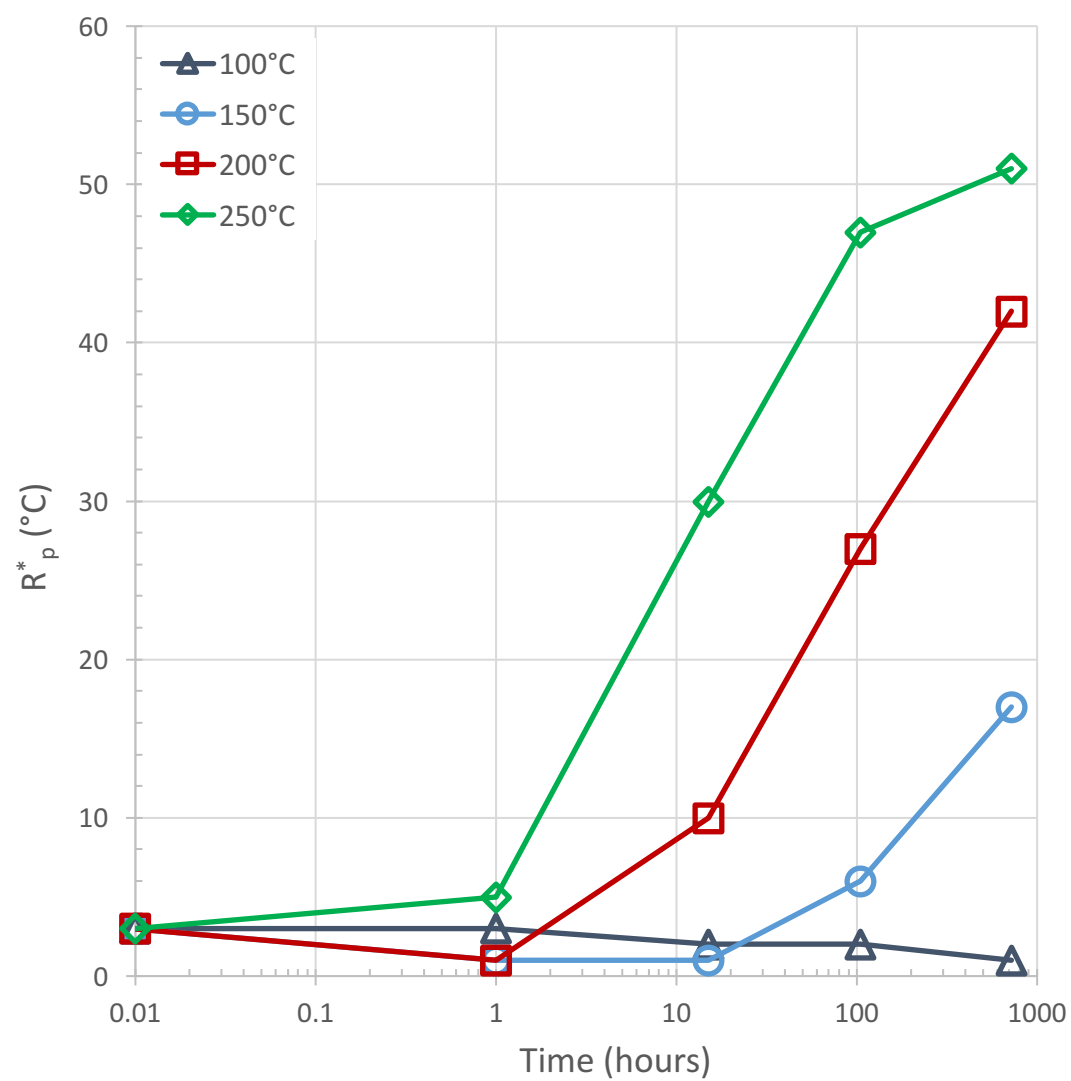
Sample with Retained CW & Precipitates – Aged at 250°C



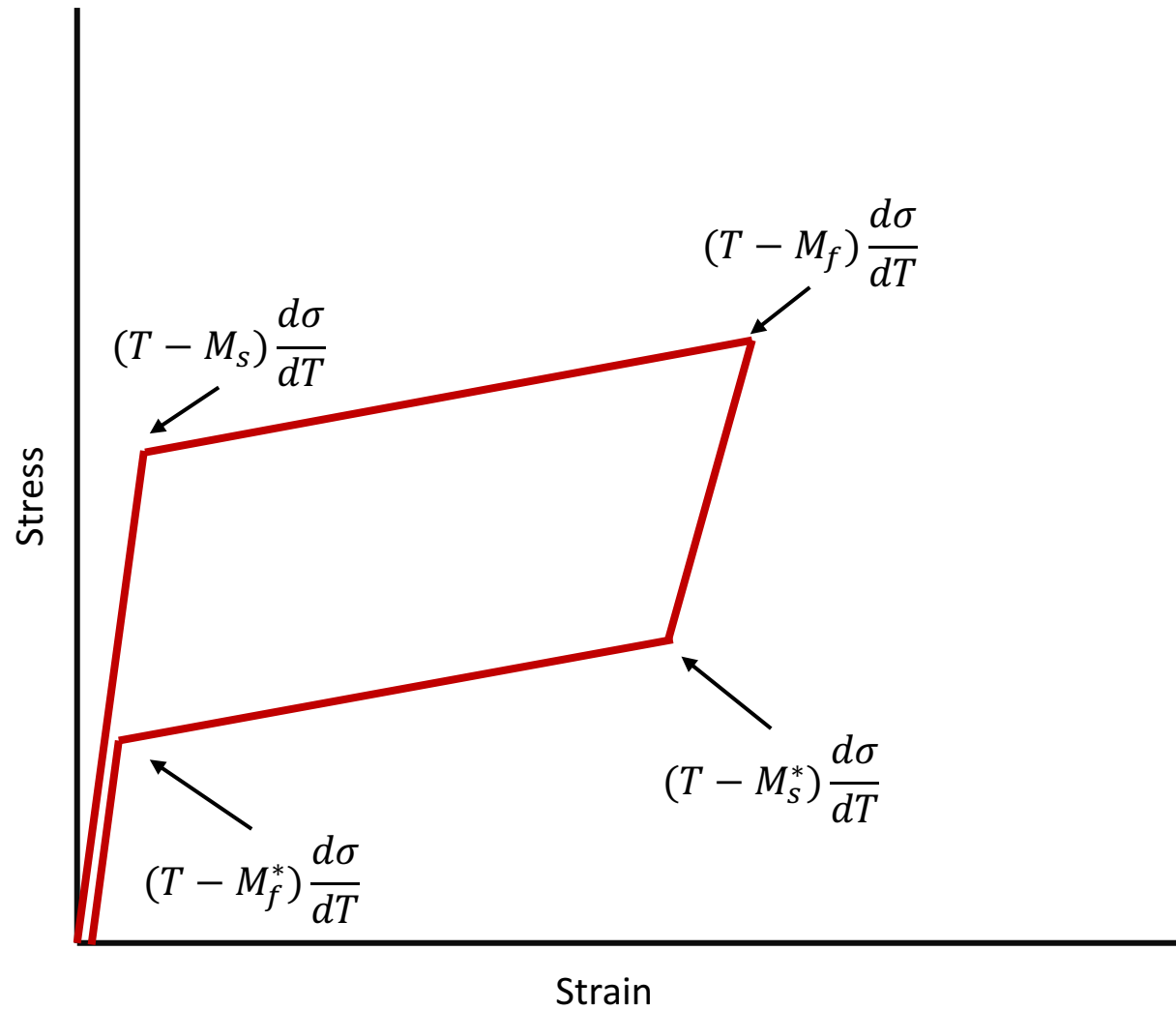
Evolution of Martensite Formation (M_p) and Reversion (M_p^*)



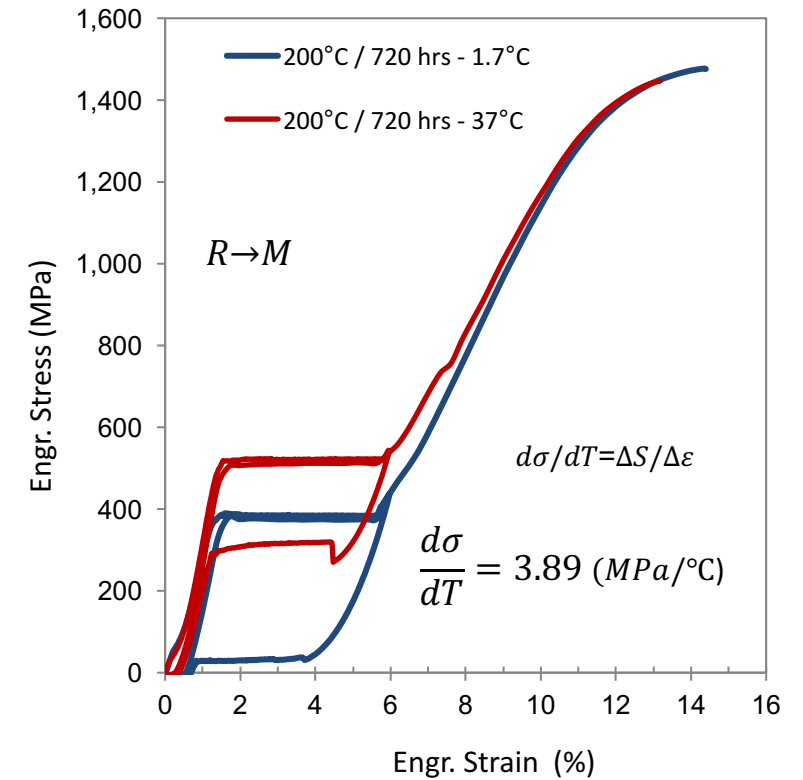
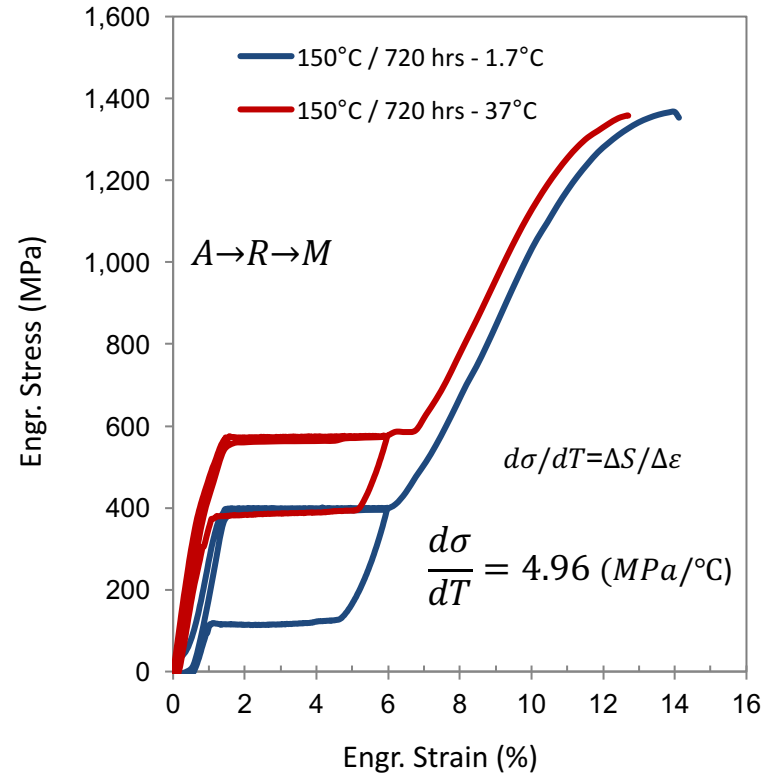
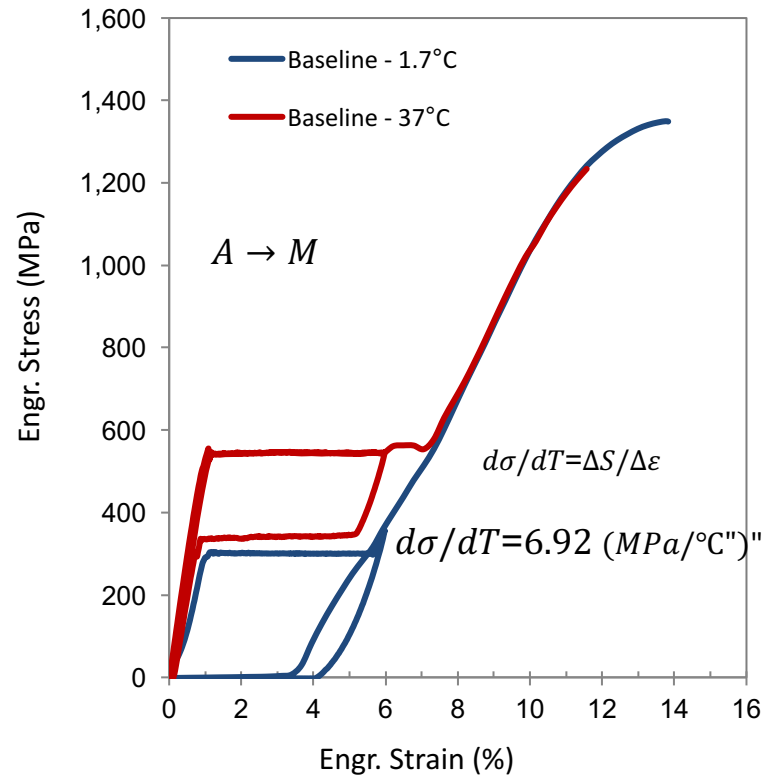
Evolution of R-Phase (R_p^*) and Peak Separation ($R_p - M_p$)



Clausius-Clapeyron – Relation between Stress and Temperature



Stabilization of “R-Phase” and its effect on “Stress”



Remarks & Conclusions:

- Ni-rich Ti-Ni is metastable even at temperatures as low as 100°C
- Exposures at temperatures $\leq 150^\circ\text{C}$ resulted in stiffening of the material due to the suppression of Martensite formation (M_p) & reversion (M_p^*)
- Suppression of Martensite could be attributed to Ni clustering, precipitation, or the coherency of the precipitates OR a combination of all
- Exposures at temperatures $> 150^\circ\text{C}$ resulted in loss of stiffness
- Loss of stiffness is attributed to the decrease in $d\sigma/dT$ due to stabilization of the R-phase
- Stabilization of the R-phase at higher temperatures can also result in materials with an A_f well above body temperature (i.e. 48°C) with pseudoelasticity!
- Caution must be taken when exposing NiTi to temperatures $< 200^\circ\text{C}$ (e.g. when applying coatings)

bit.ly/smst17ndc

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SMST2017

SHAPE MEMORY AND SUPERELASTIC TECHNOLOGIES CONFERENCE AND EXPOSITION

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