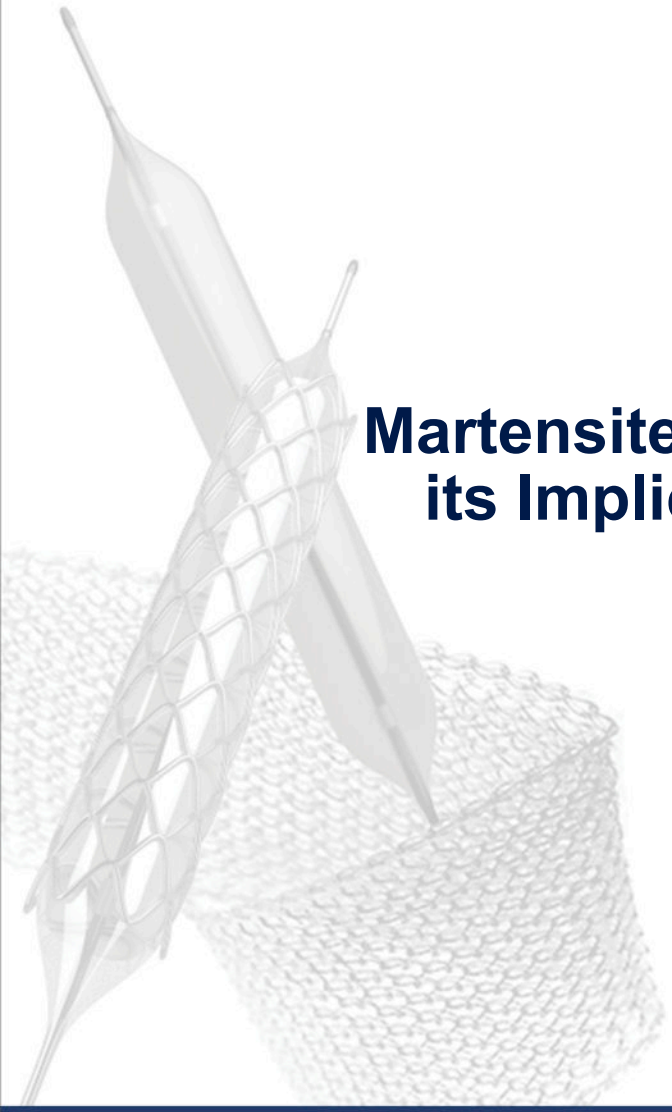
Martensite/R-phase Superelasticity and its Implications to Nitinol Durability



Conventional “wisdom”

Superelasticity requires ambient temperatures above the A_s-A_f temperature range

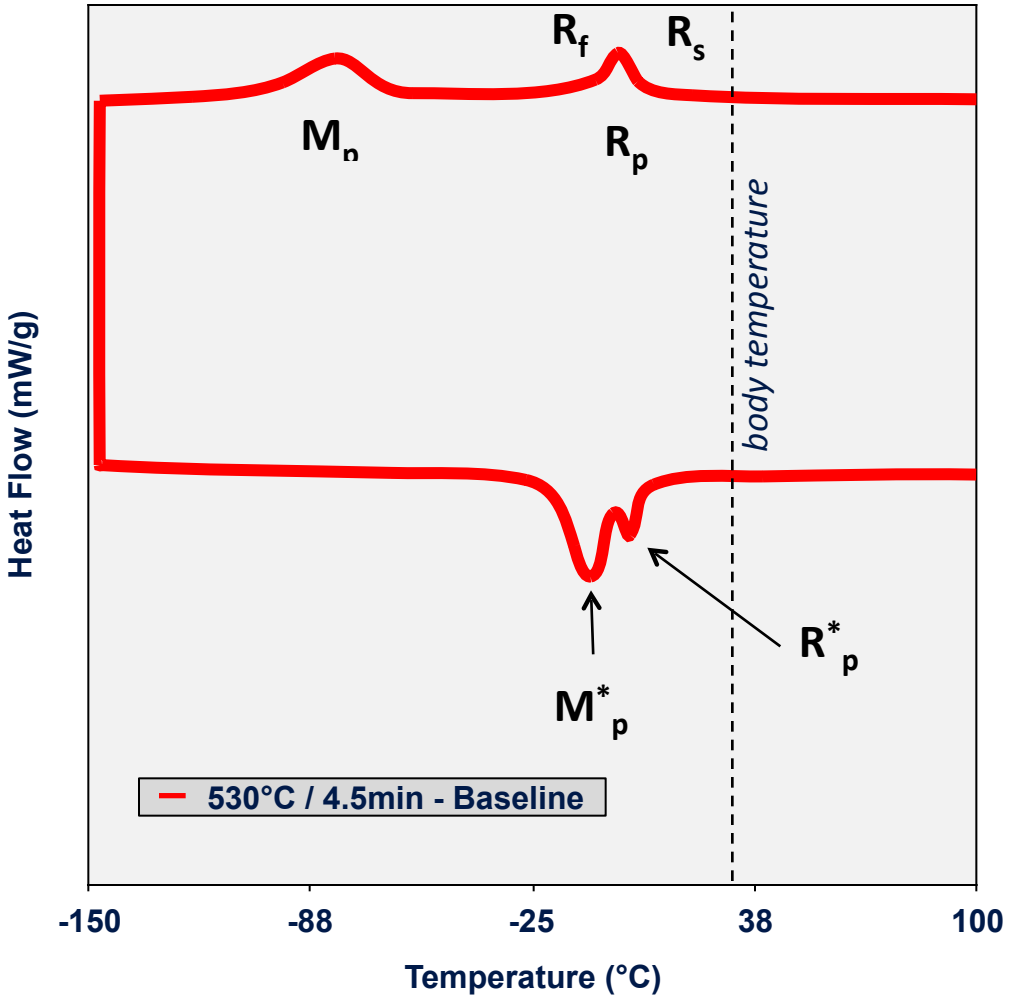
so that unloading reverts Martensite to Austenite.

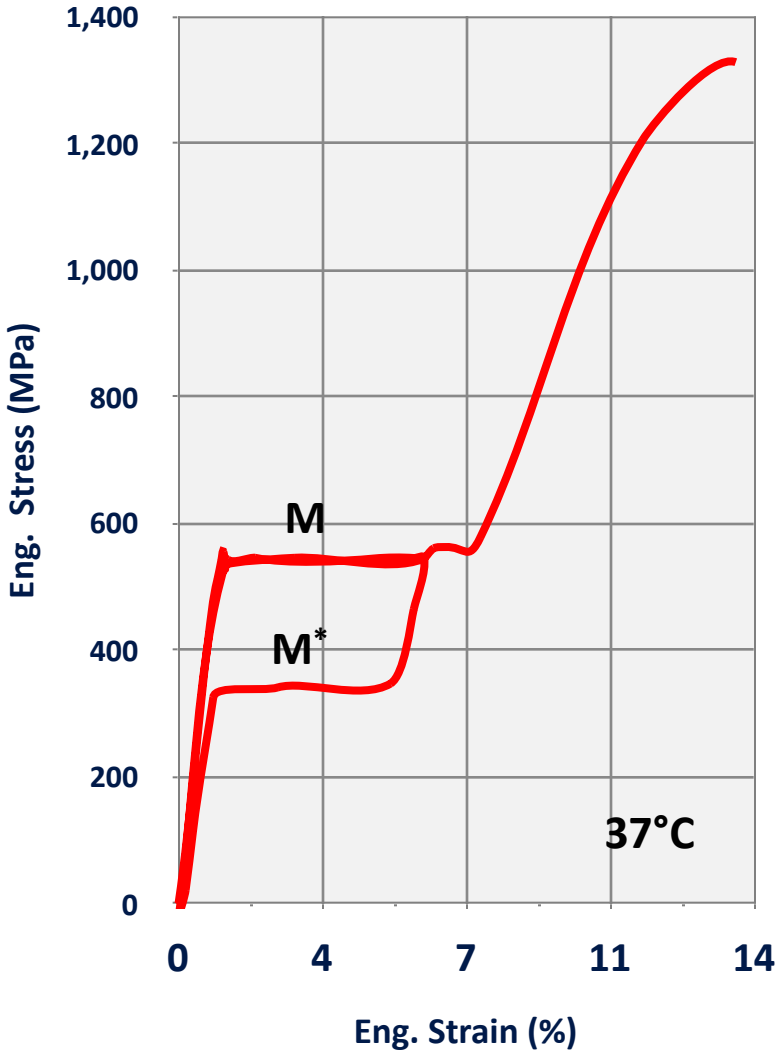
But in fact:

Superelasticity can also occur between two martensitic phases, e.g.,
between R-phase and B19’ Martensite.

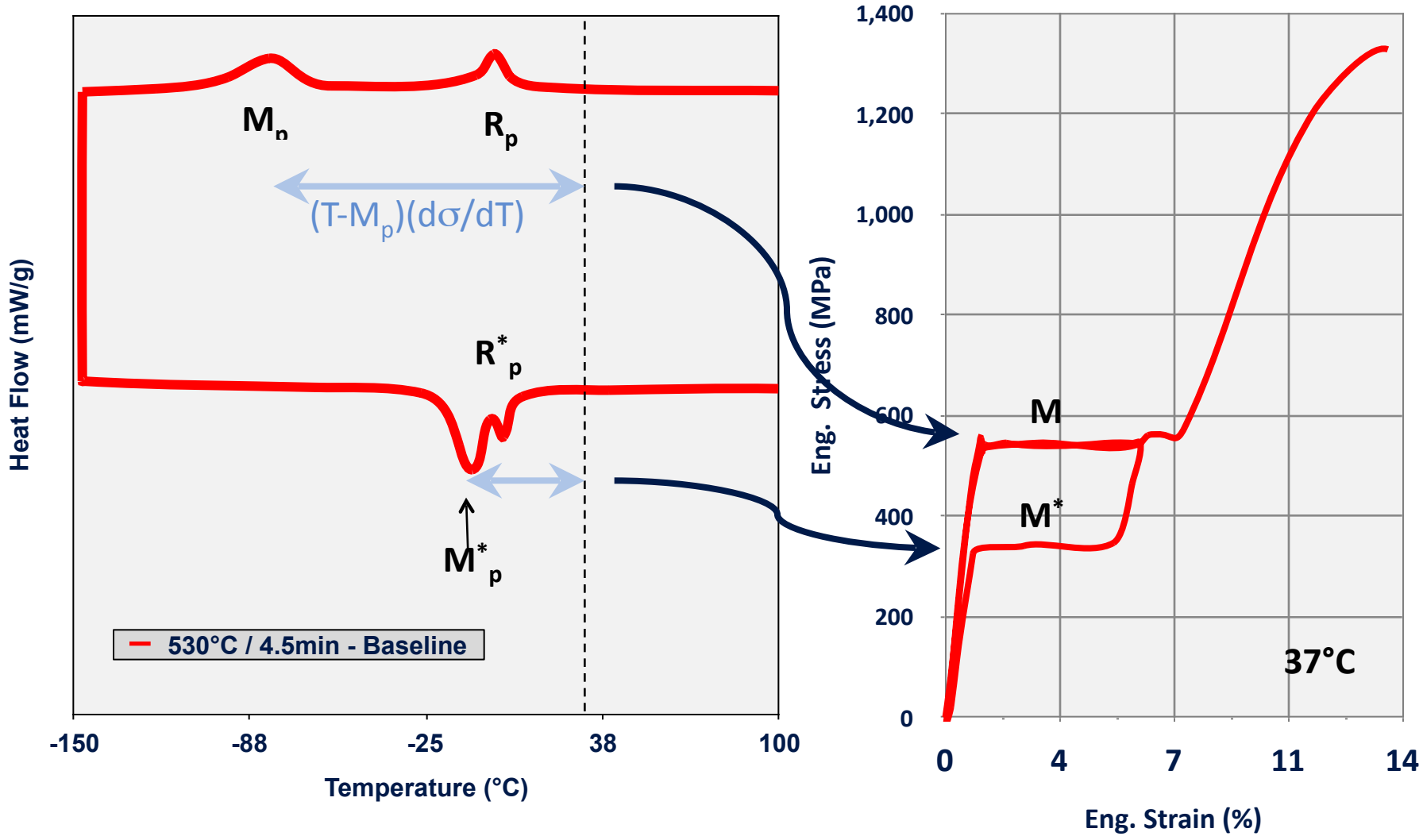
How does this affect superelastic properties?

Traditional superelastic material
R is not stress induced

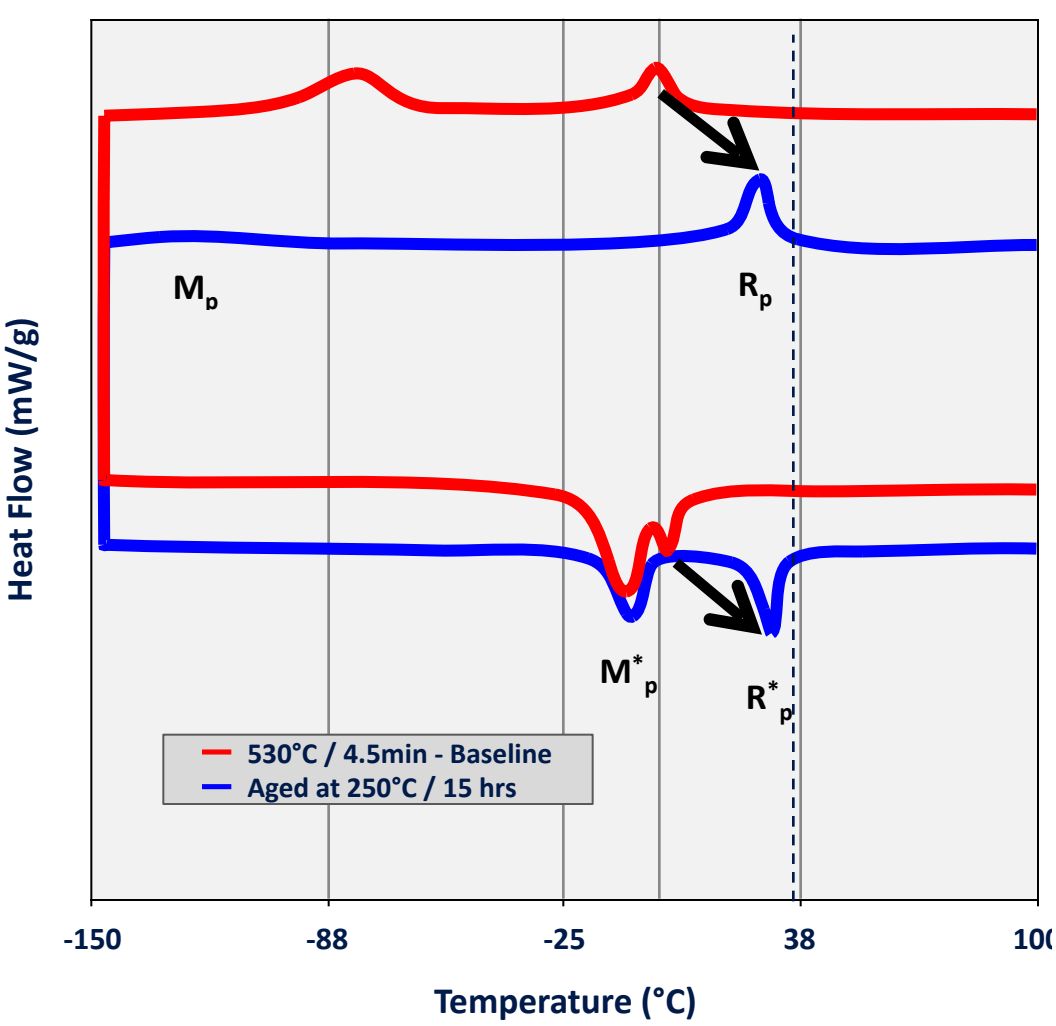


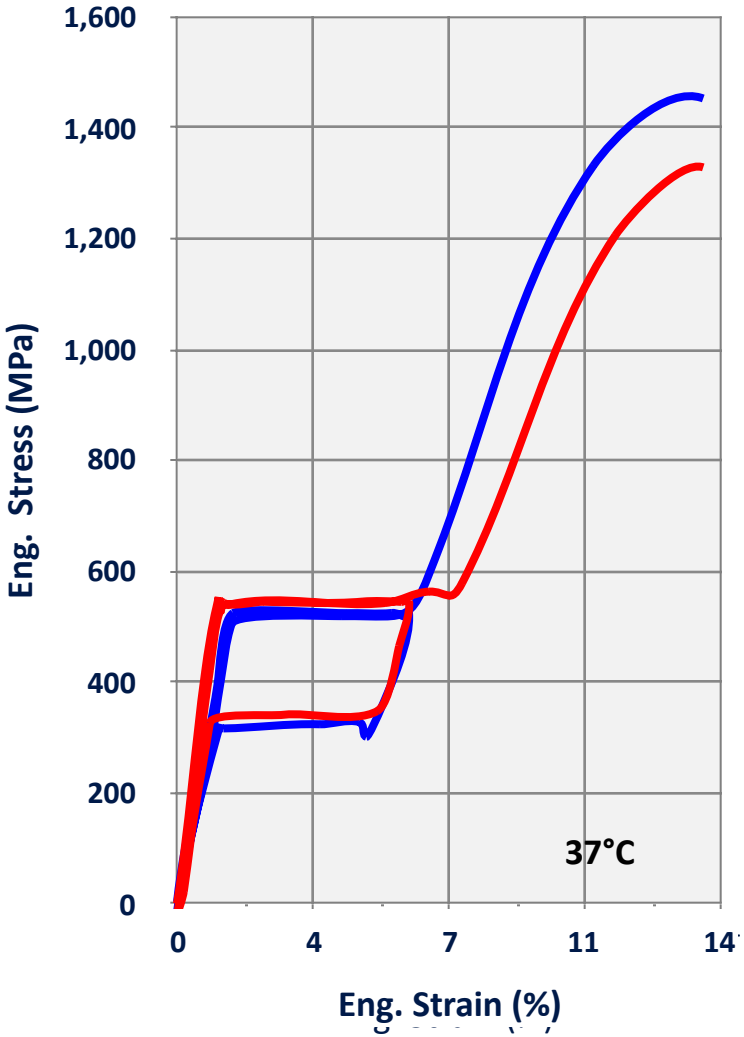


Traditional superelastic material:
M and M* reflect the upper and lower plateau stresses

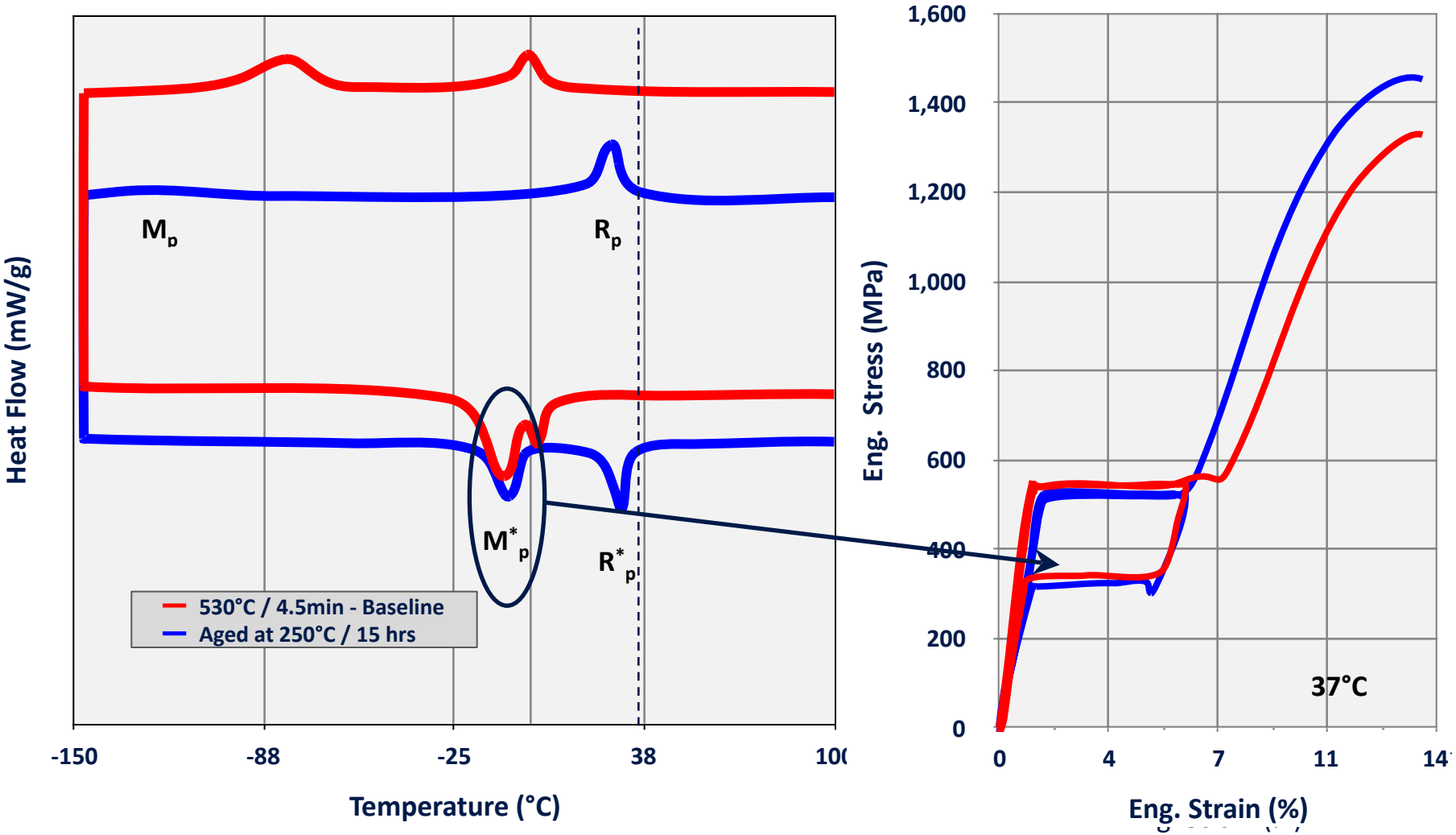


Low temperature aging stabilizes the R-phase

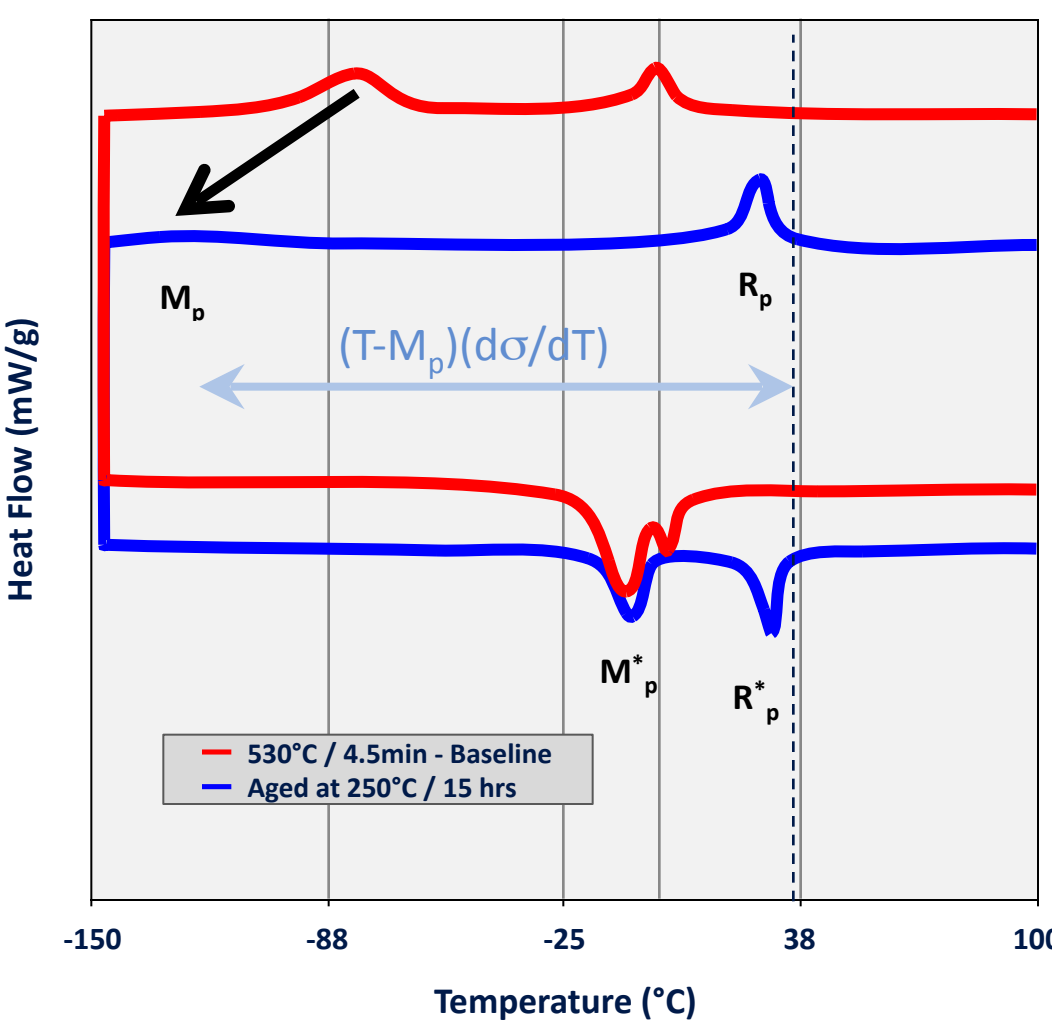


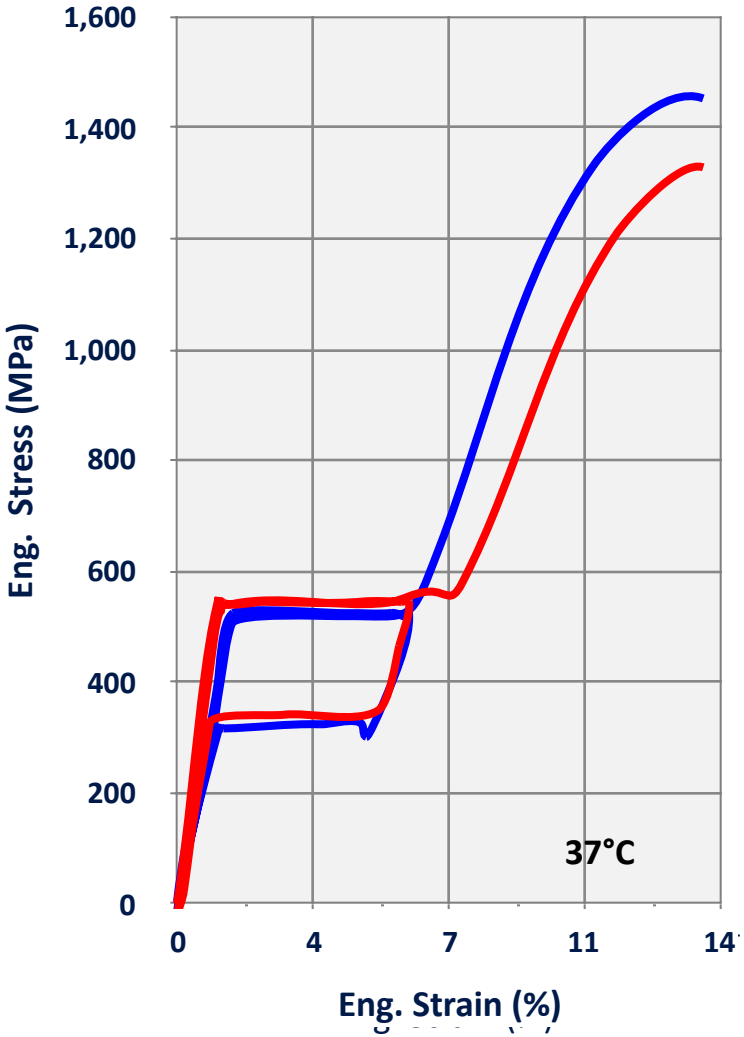


Low temperature aging does not move M*

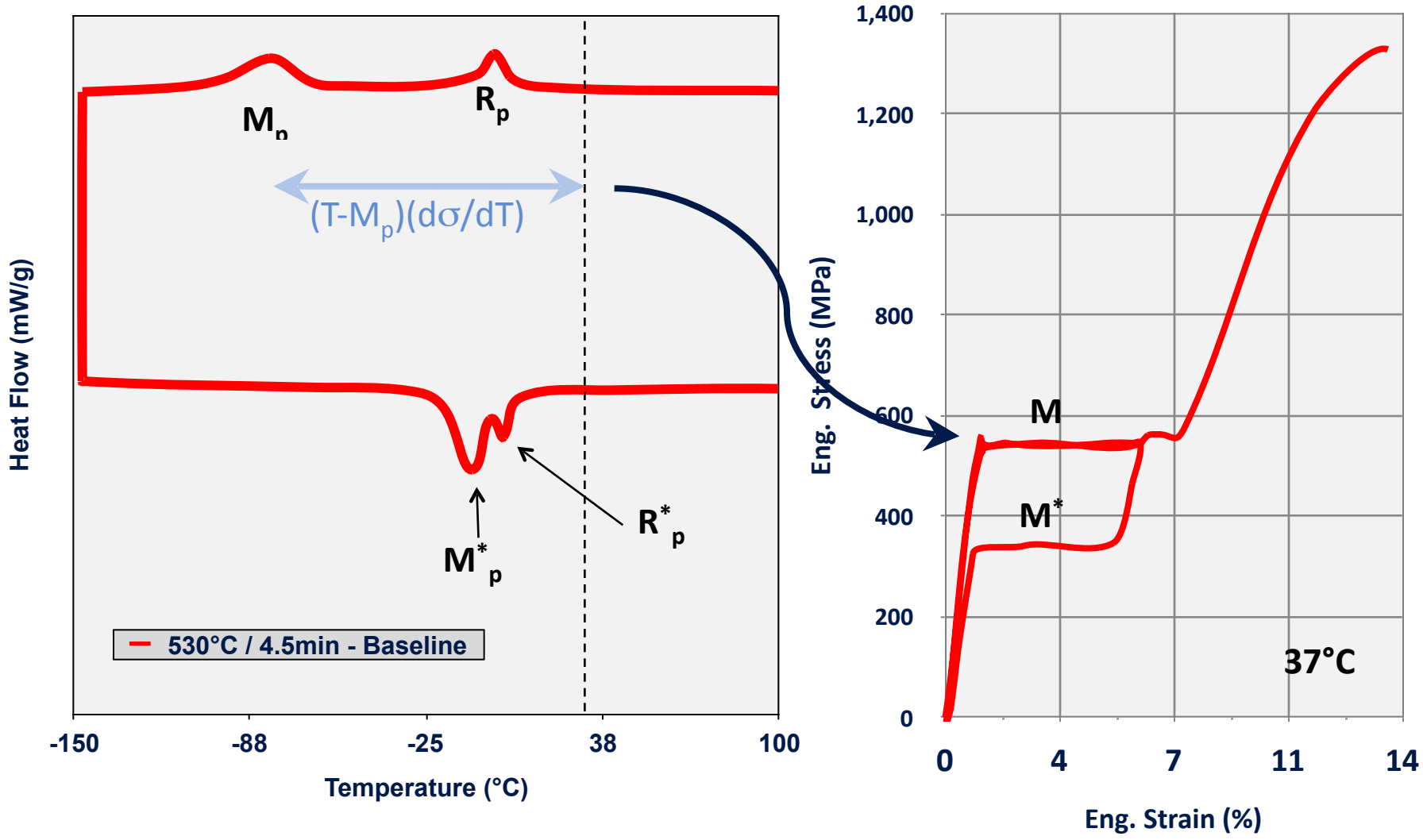


Low temperature aging suppresses M but leaves UPS unaffected?

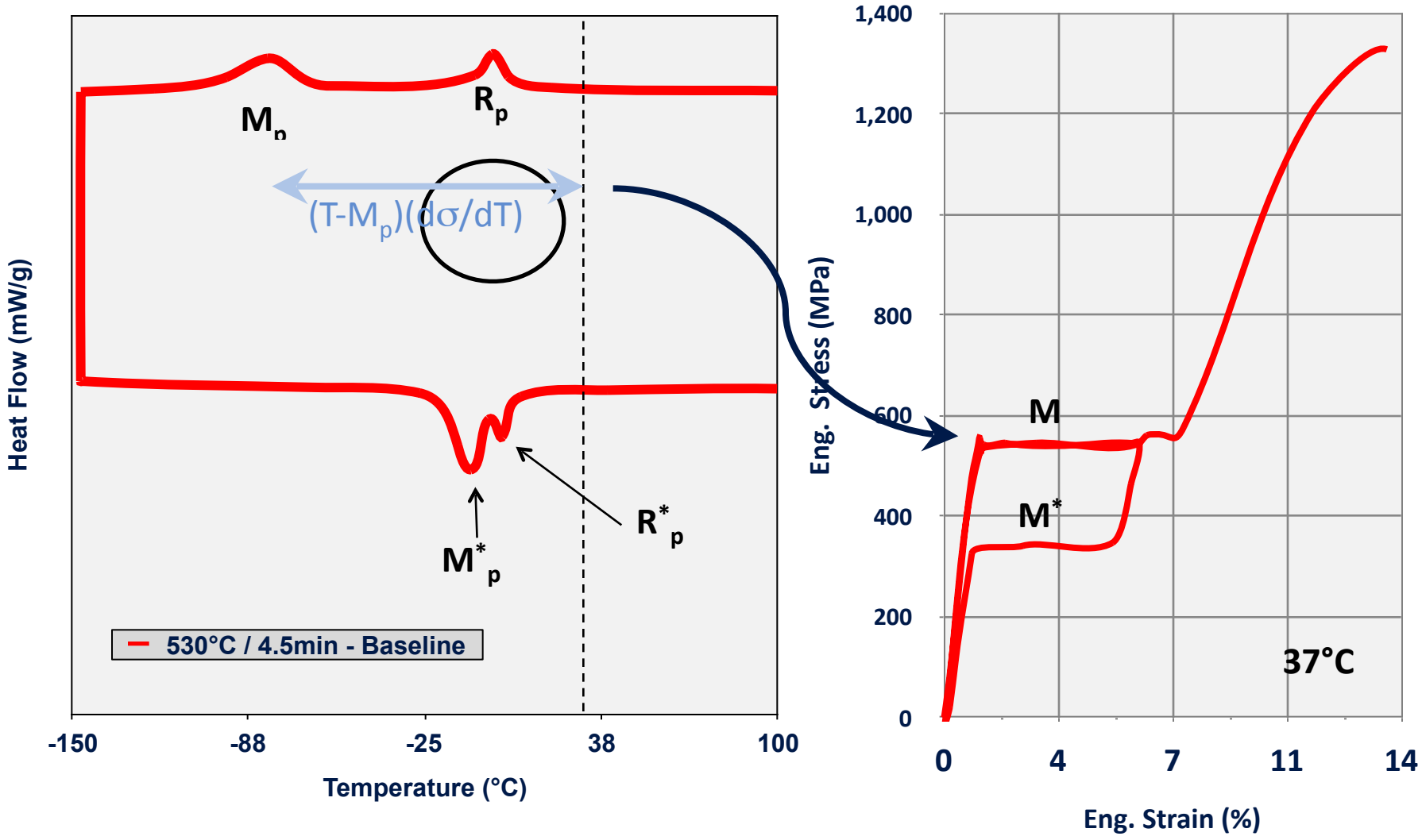




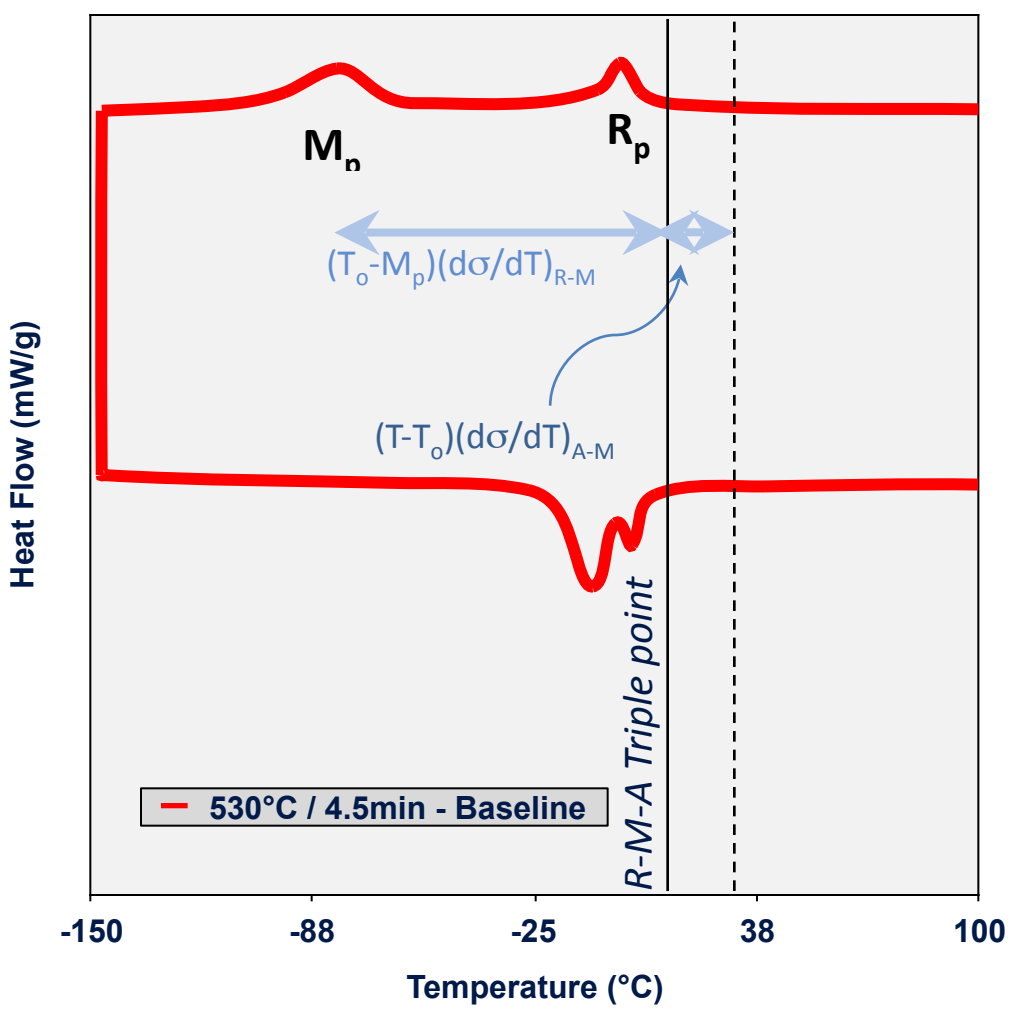
Traditional superelastic material

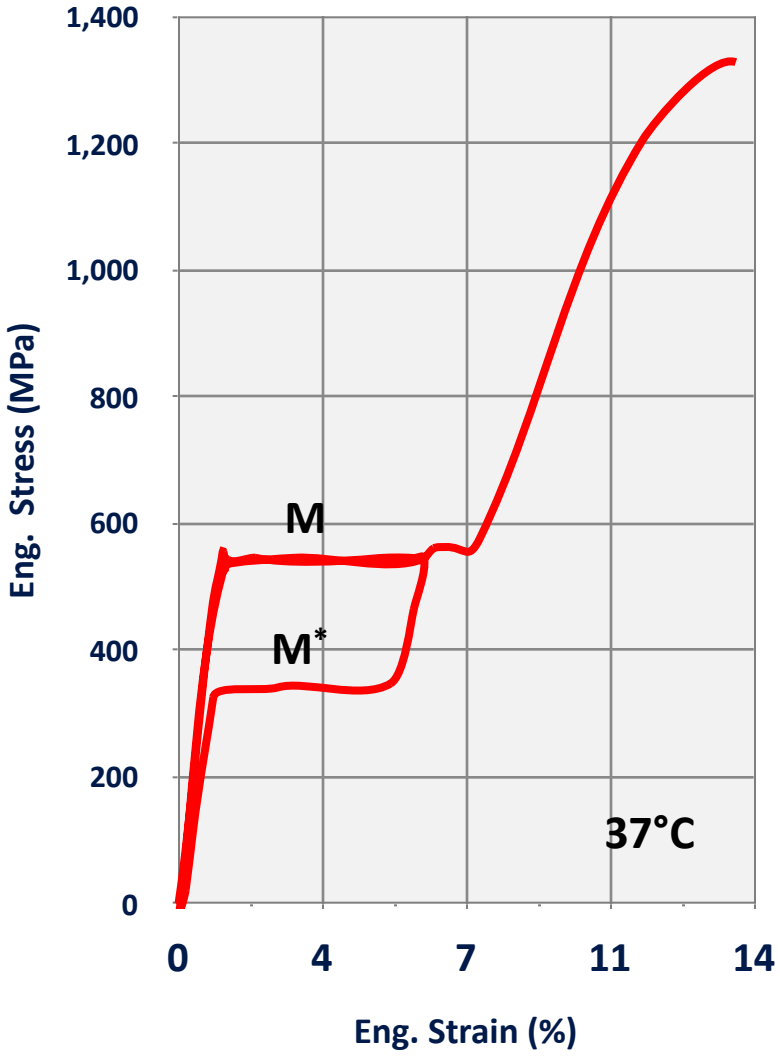


Traditional superelastic material
Which dσ/dT is operative, A-R, A-M or R-M?

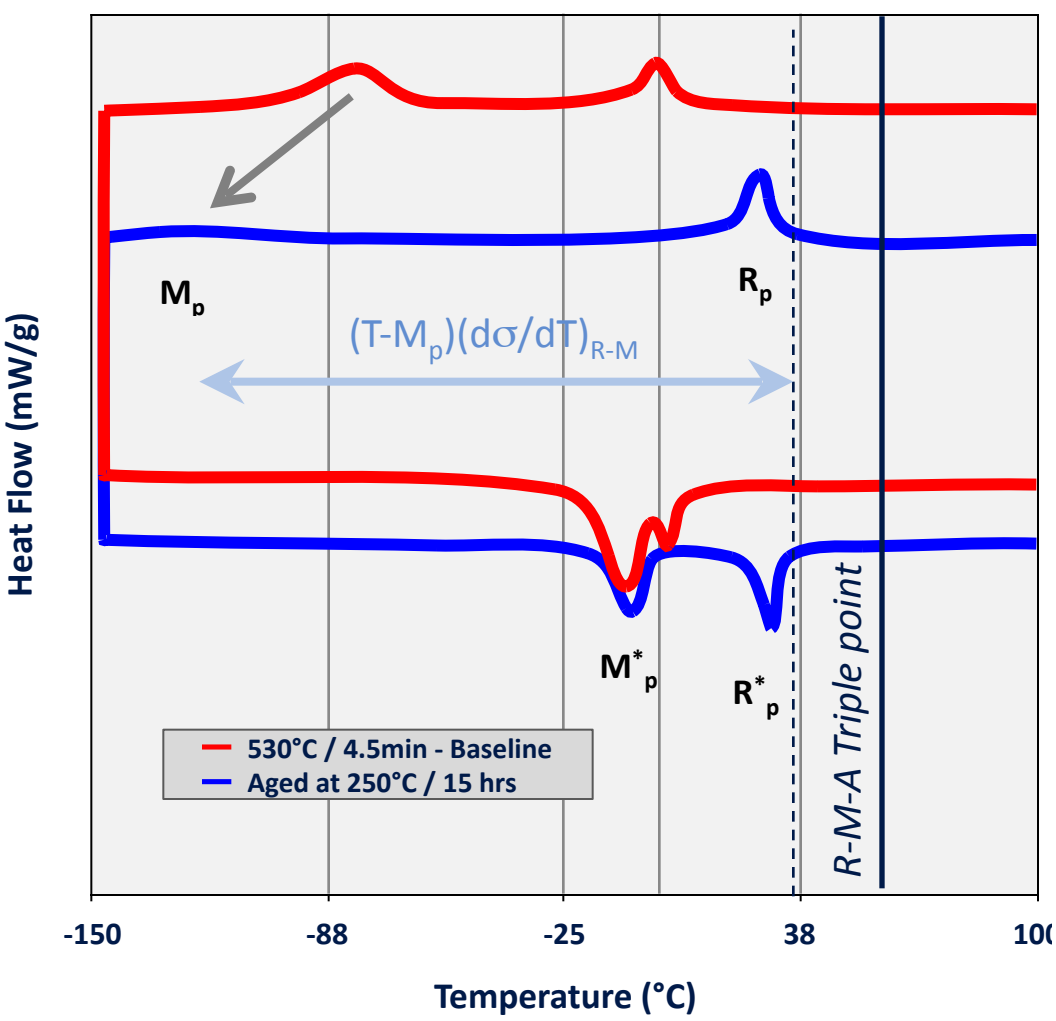


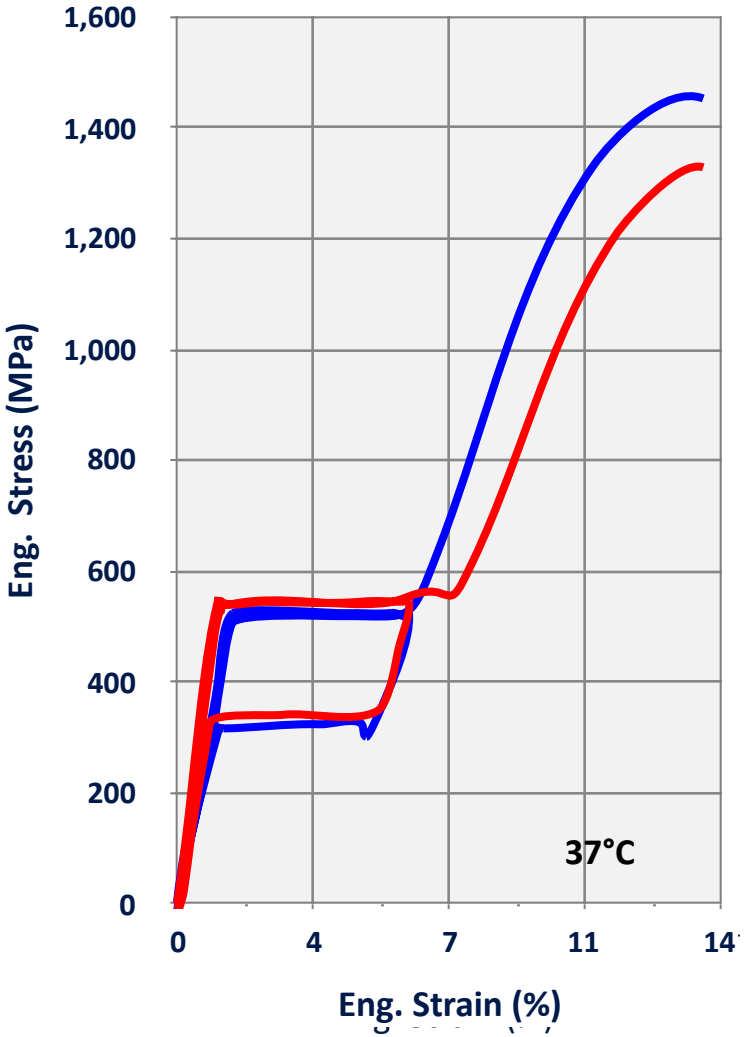
Traditional superelastic material



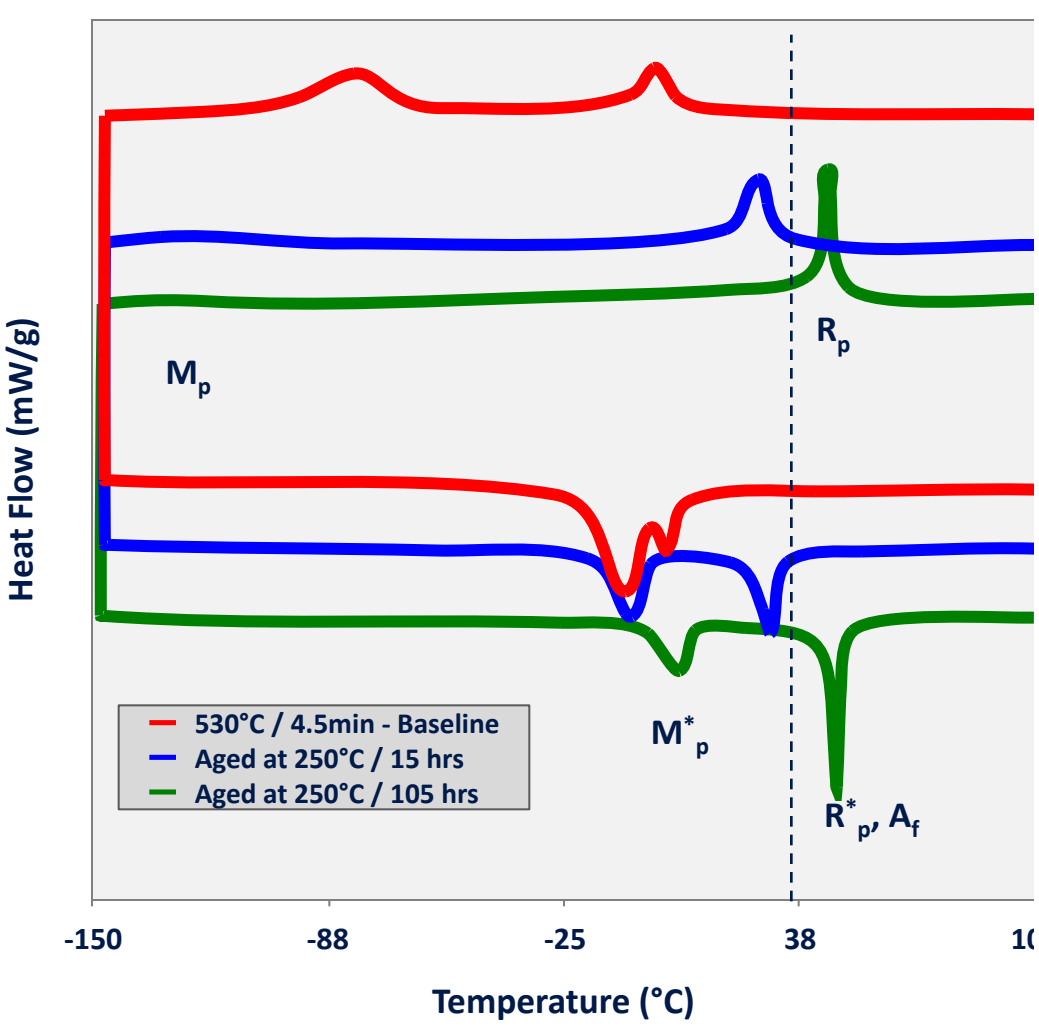


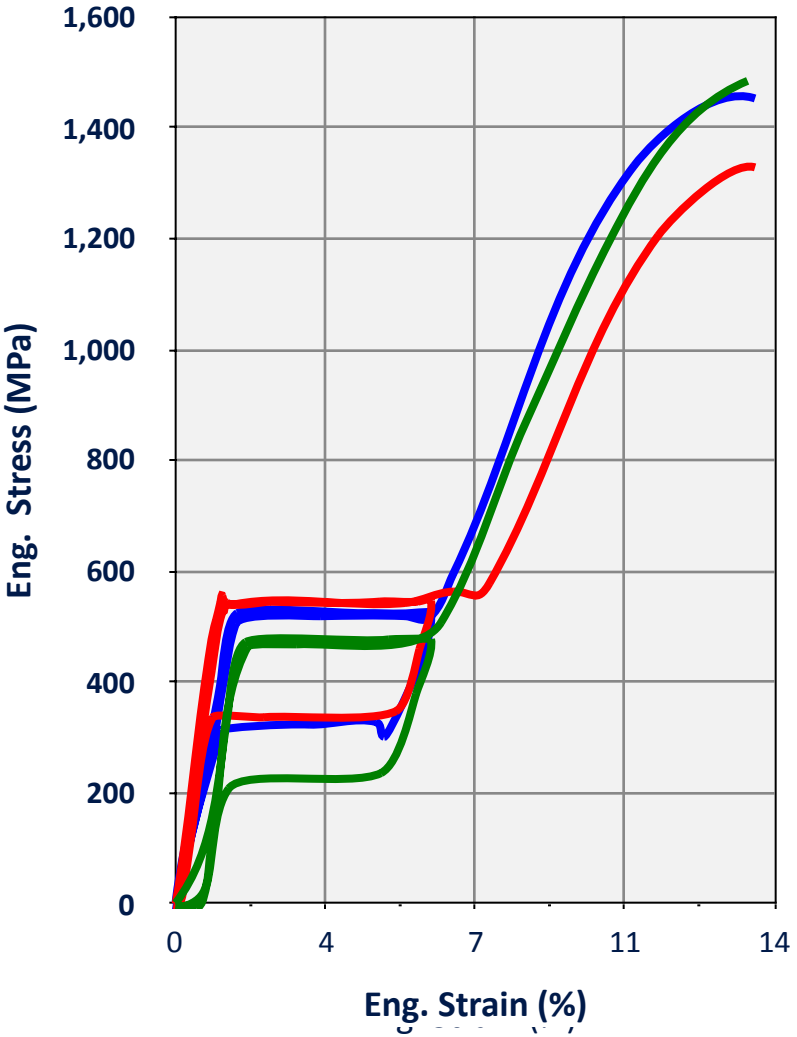
Low temperature aging decreases average dσ/dT
T is now below the triple point



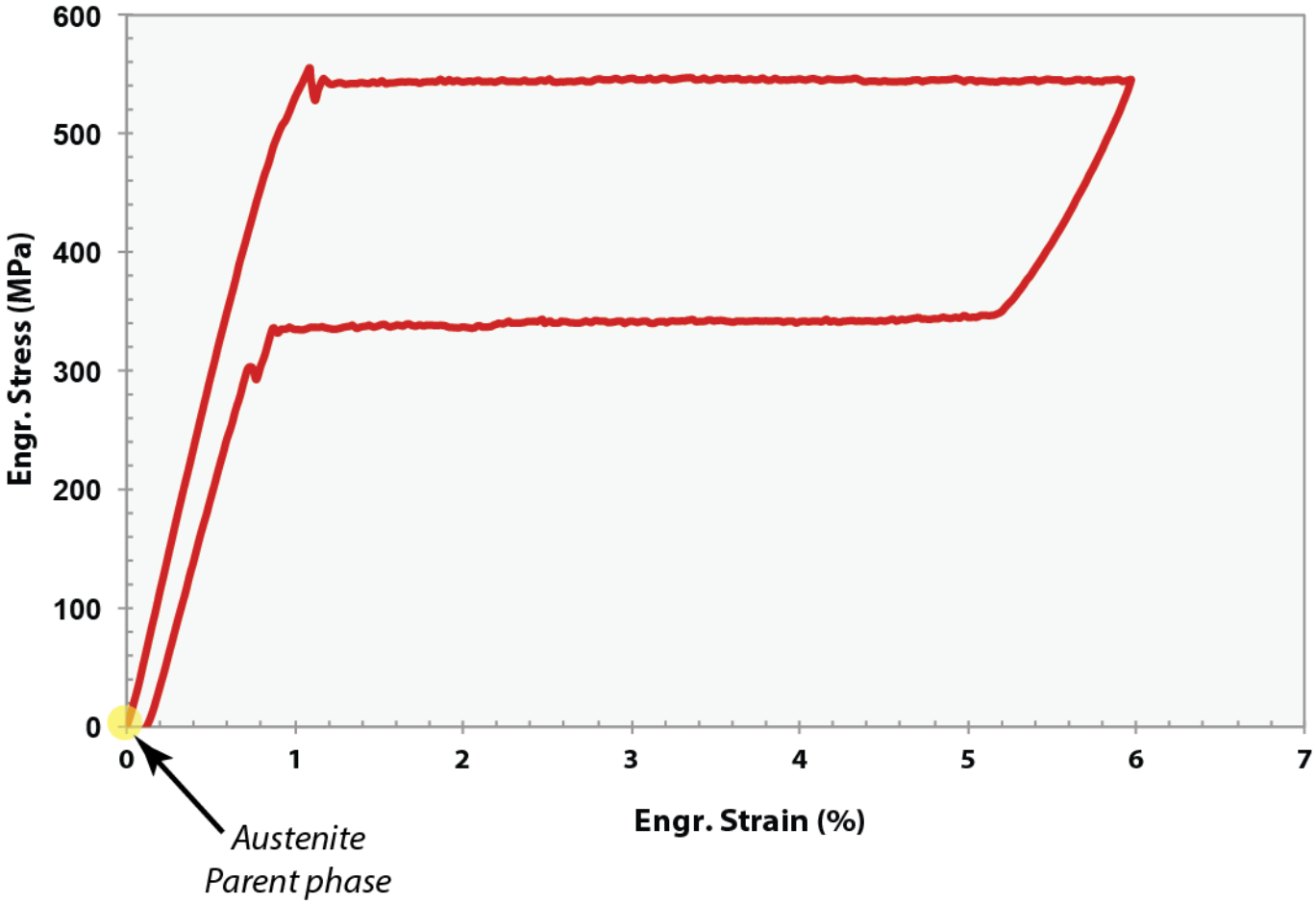


Further aging drives R^*_p (A_f) above 37°C
Austenite now plays no role in the superelastic process





Scenario 1:
A-M-A classical superelasticity (above the triple point):



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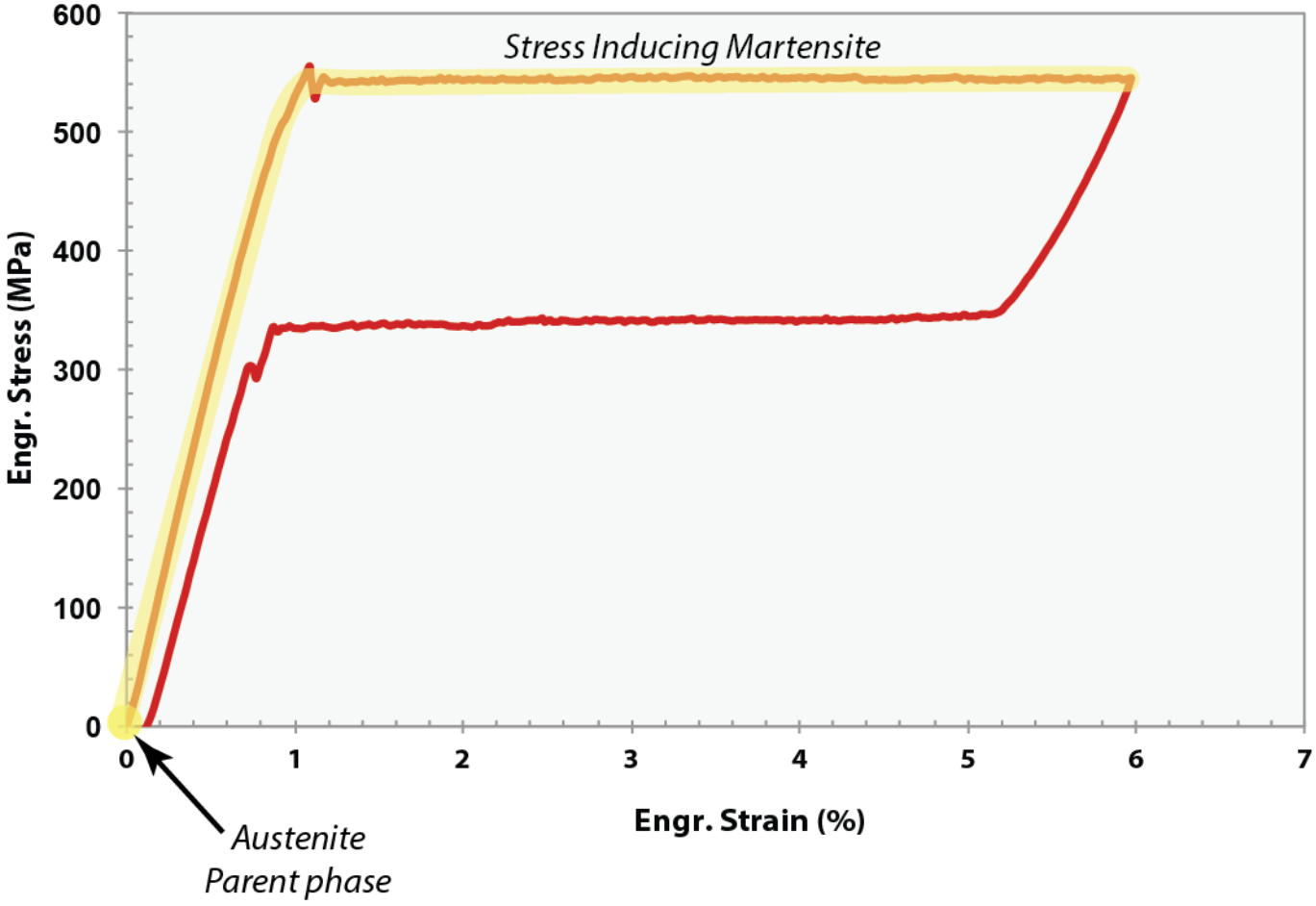
A-M-A classical superelasticity:



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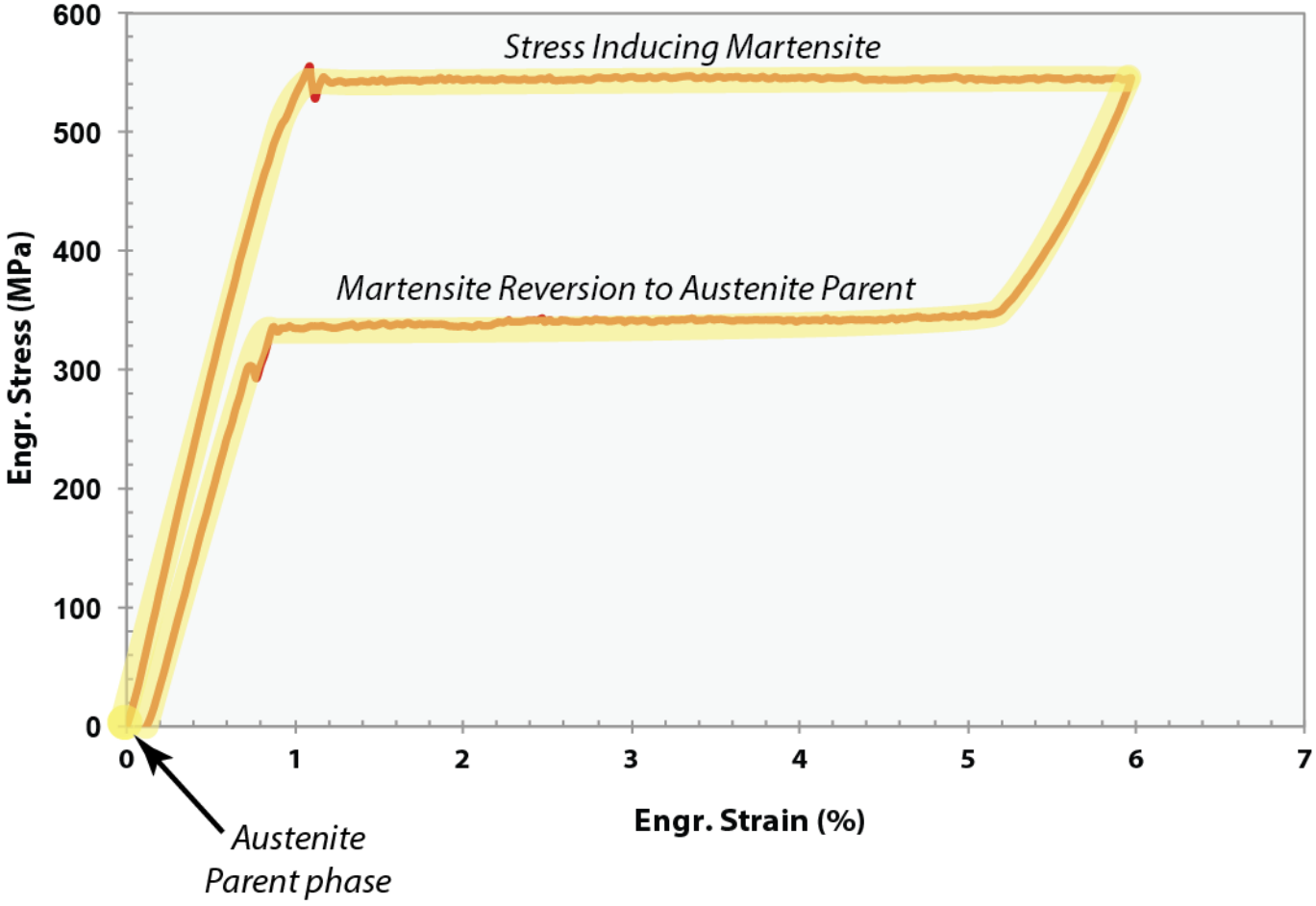
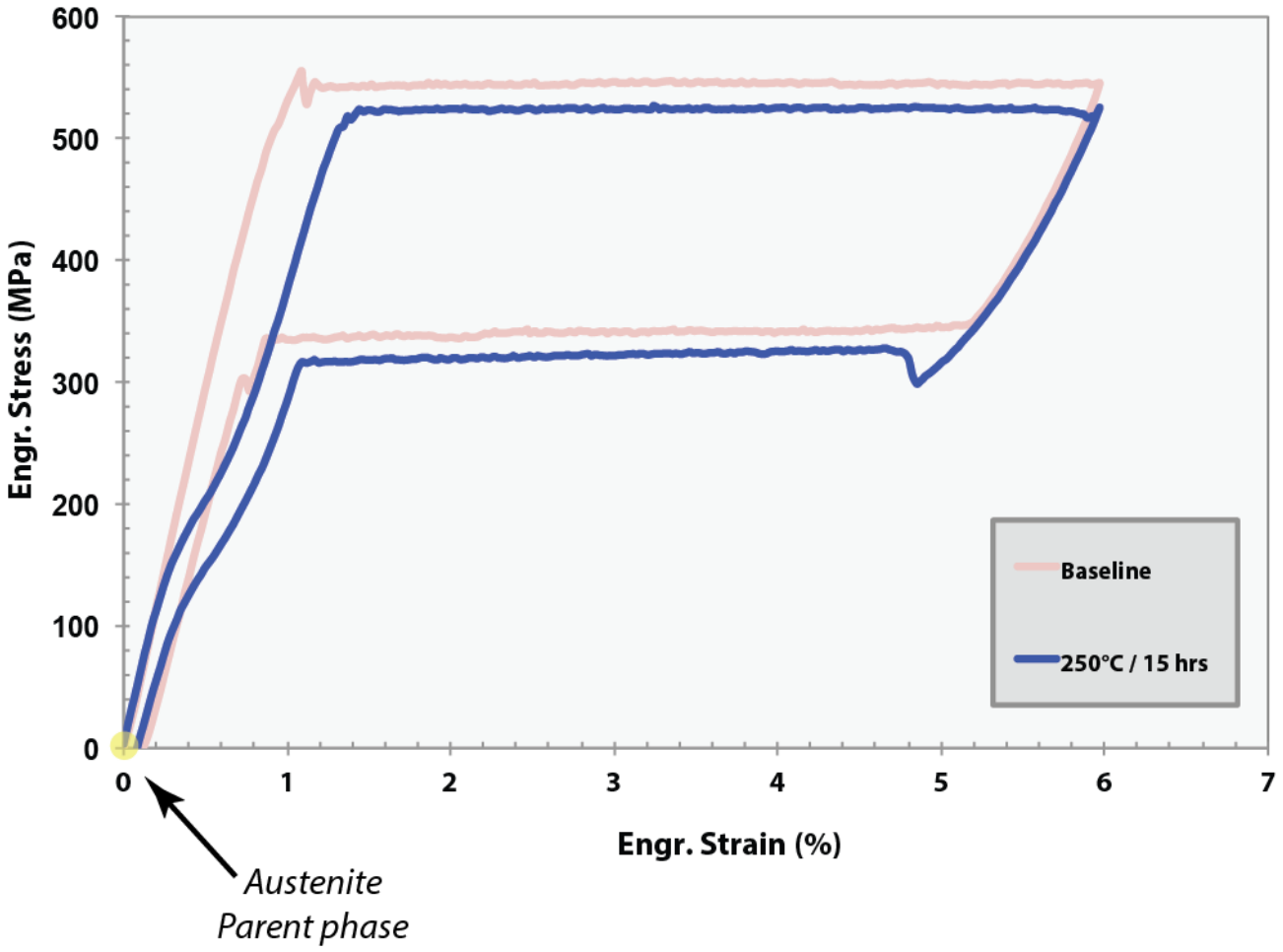
A-M-A classical superelasticity:



Scenario 2:
A-R-M-R-A superelasticity:



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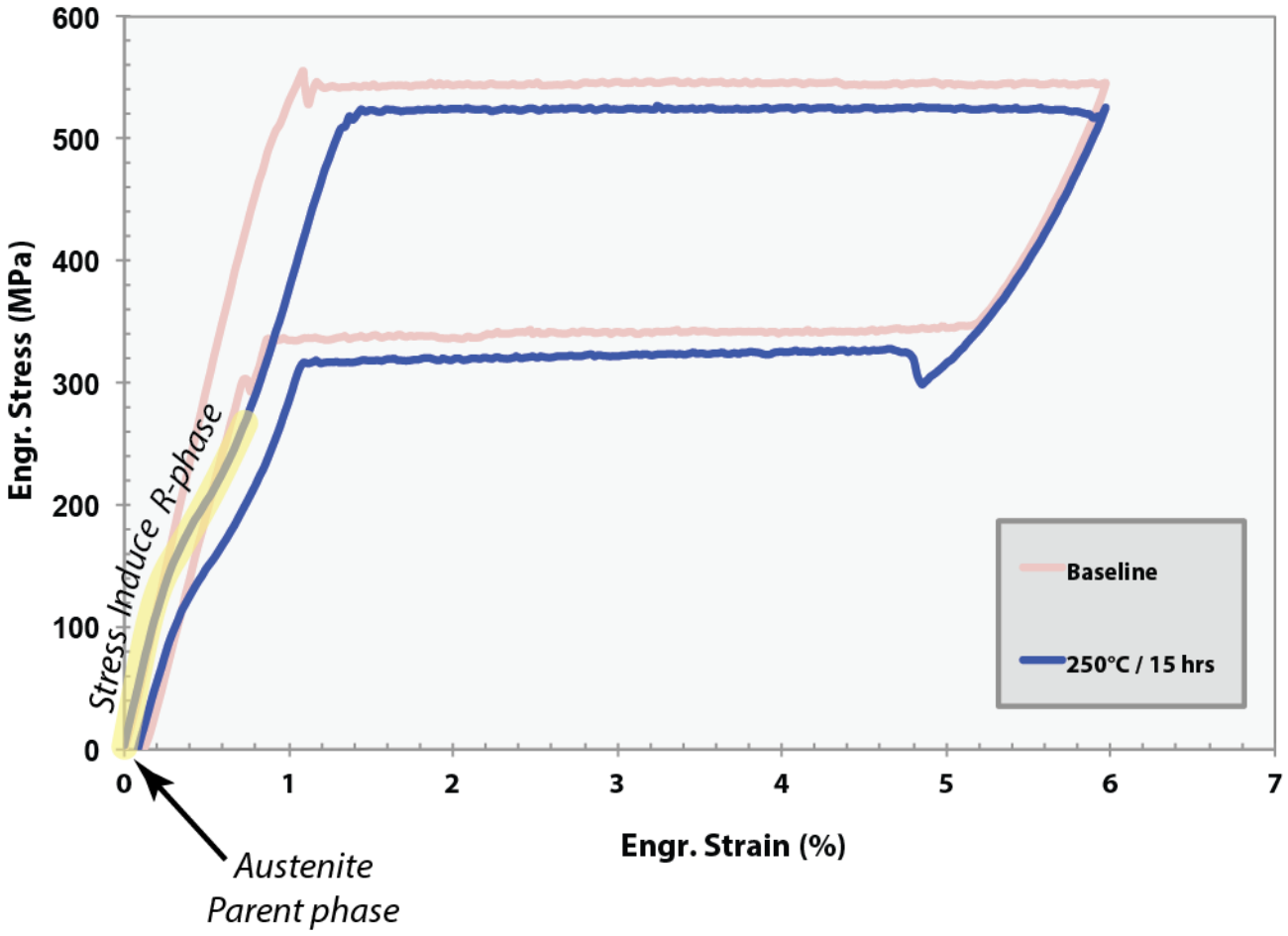

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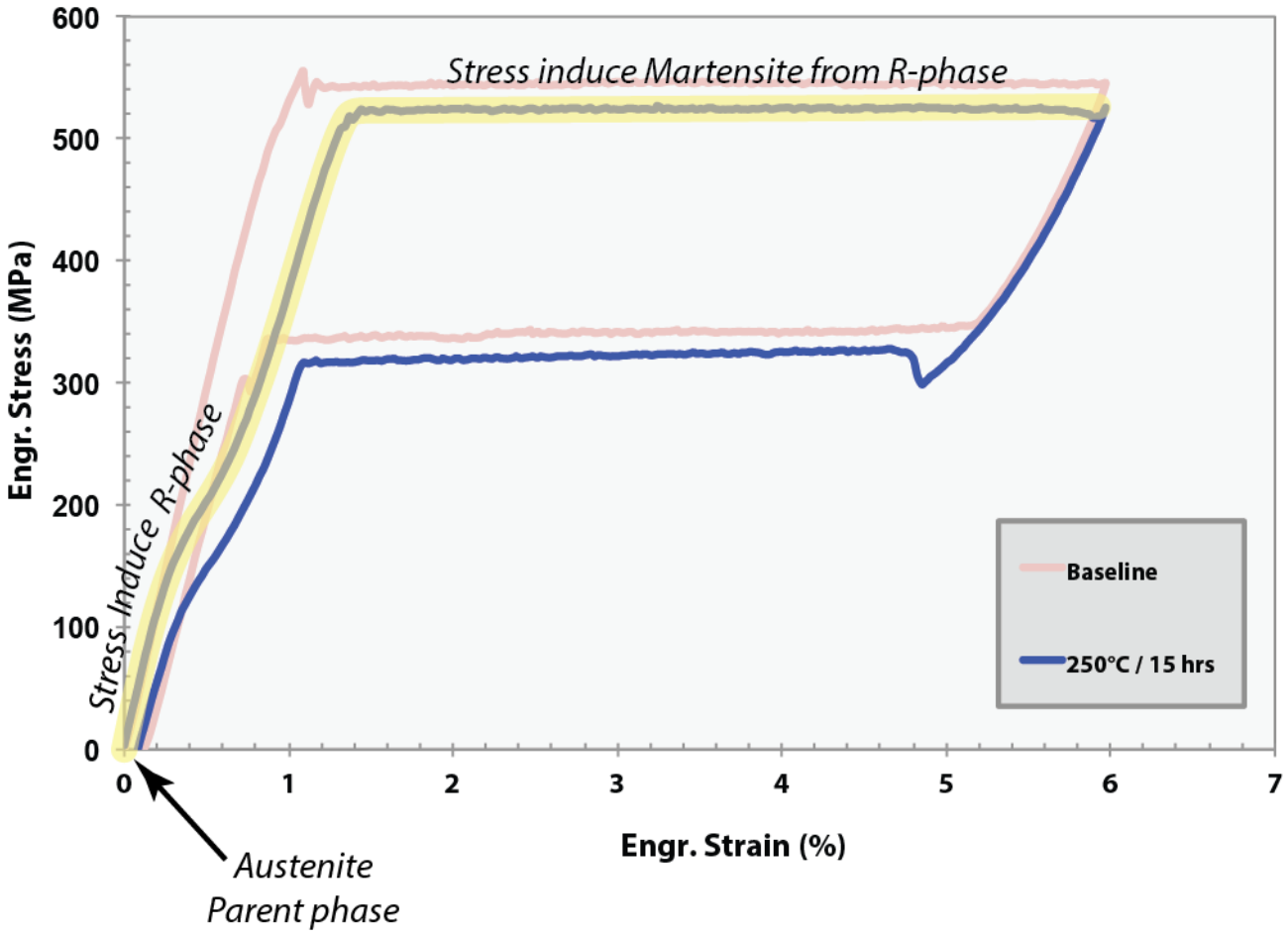

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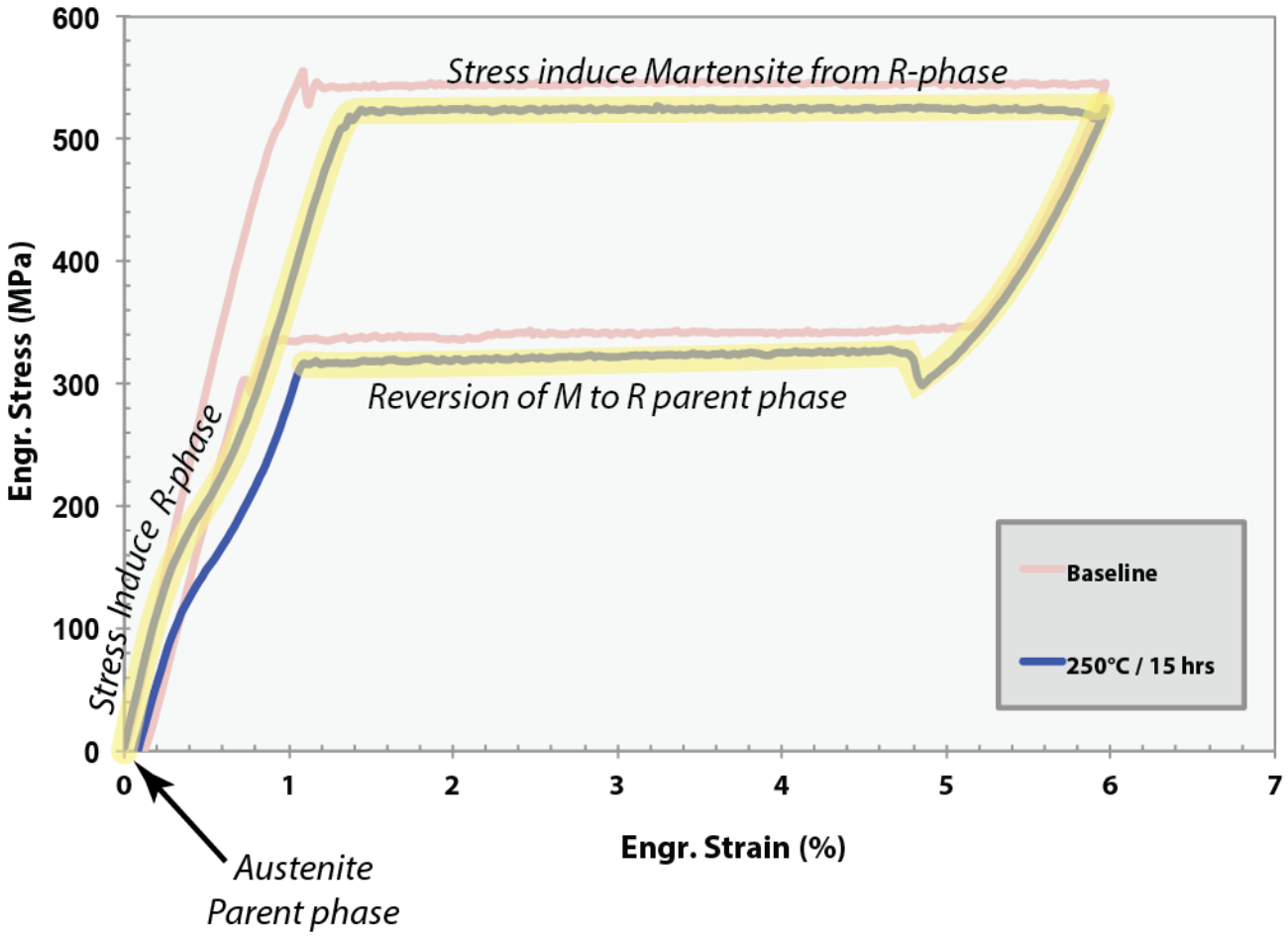

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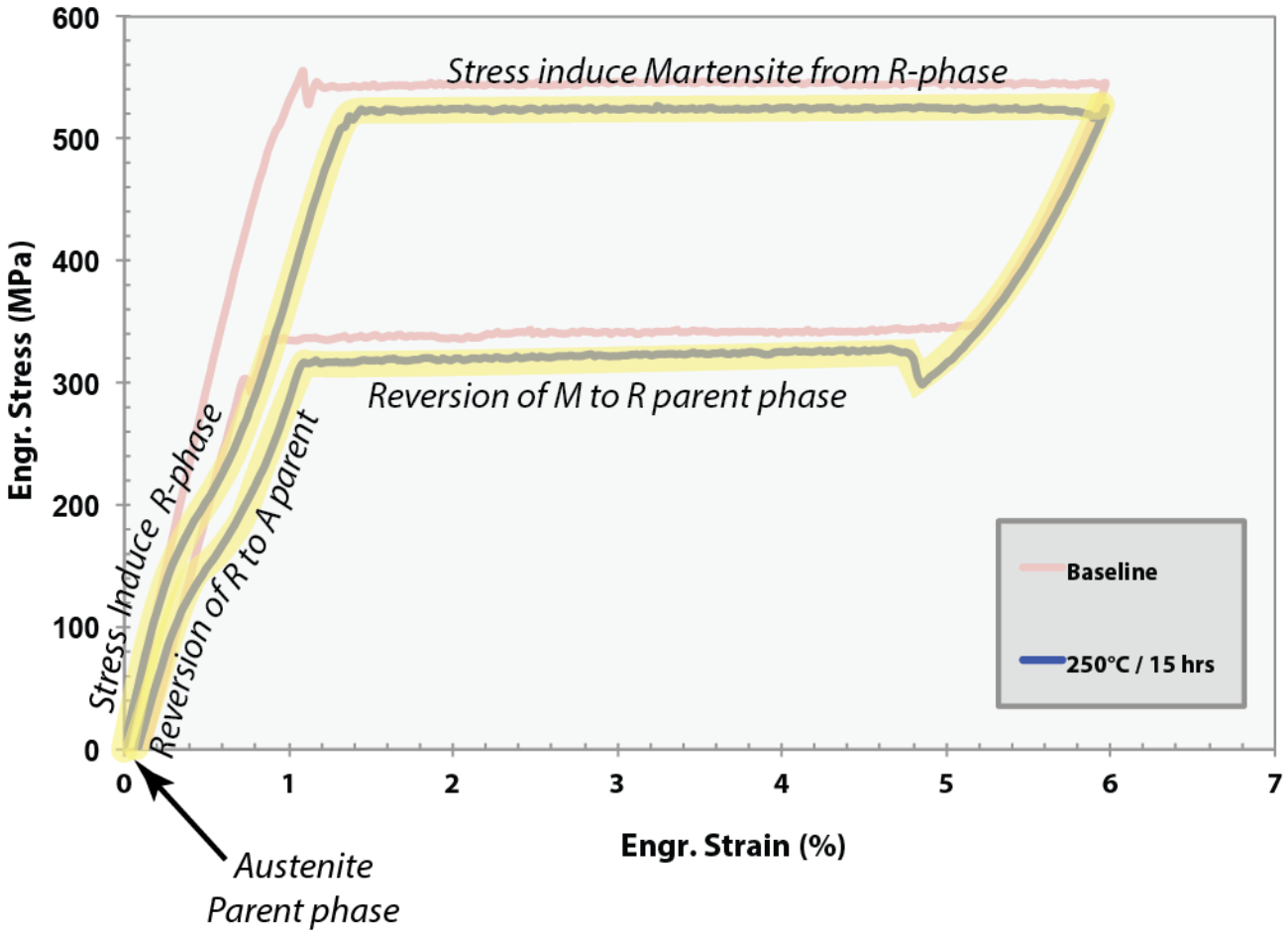
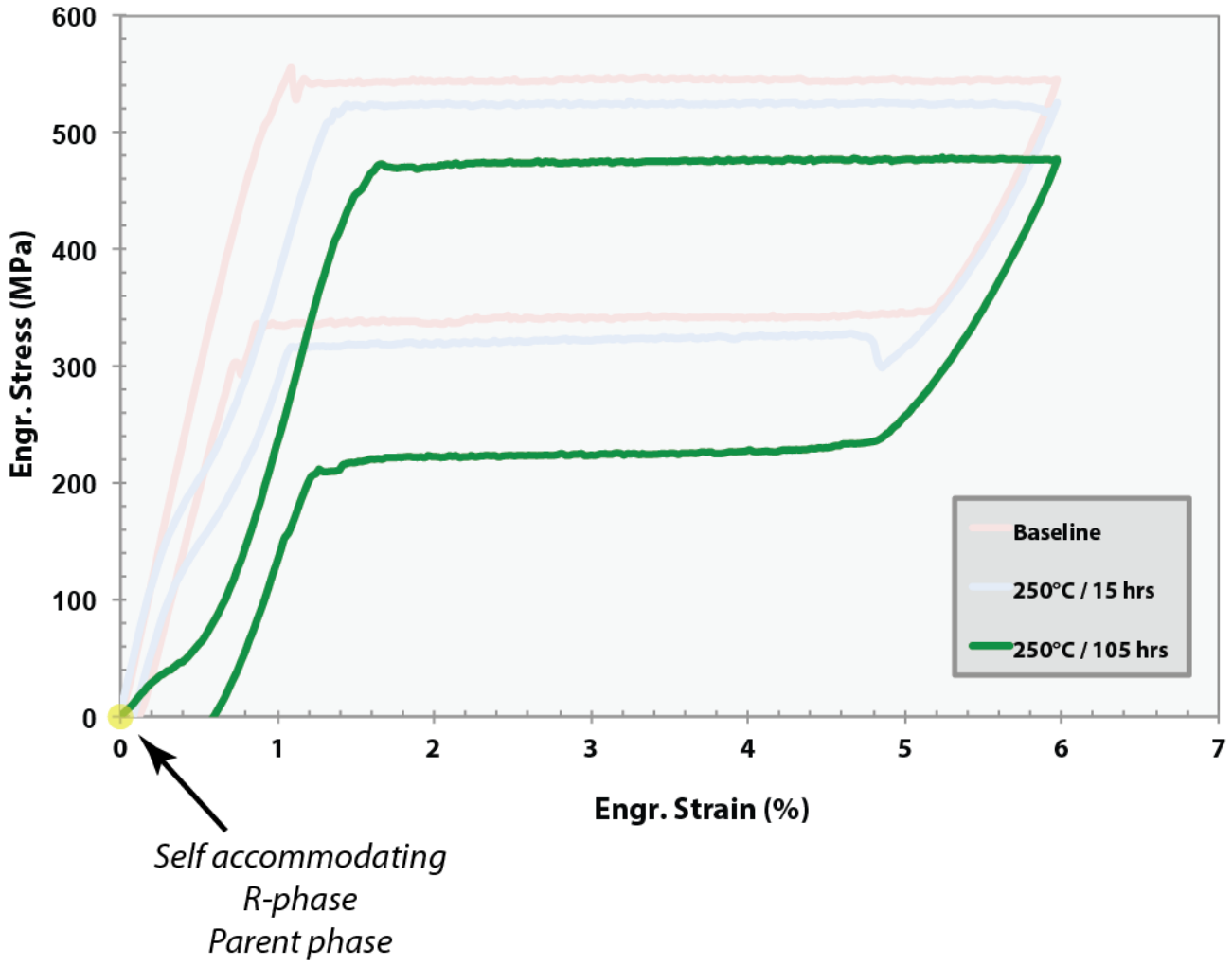


Scenario 3:
R-M-R superelasticity:



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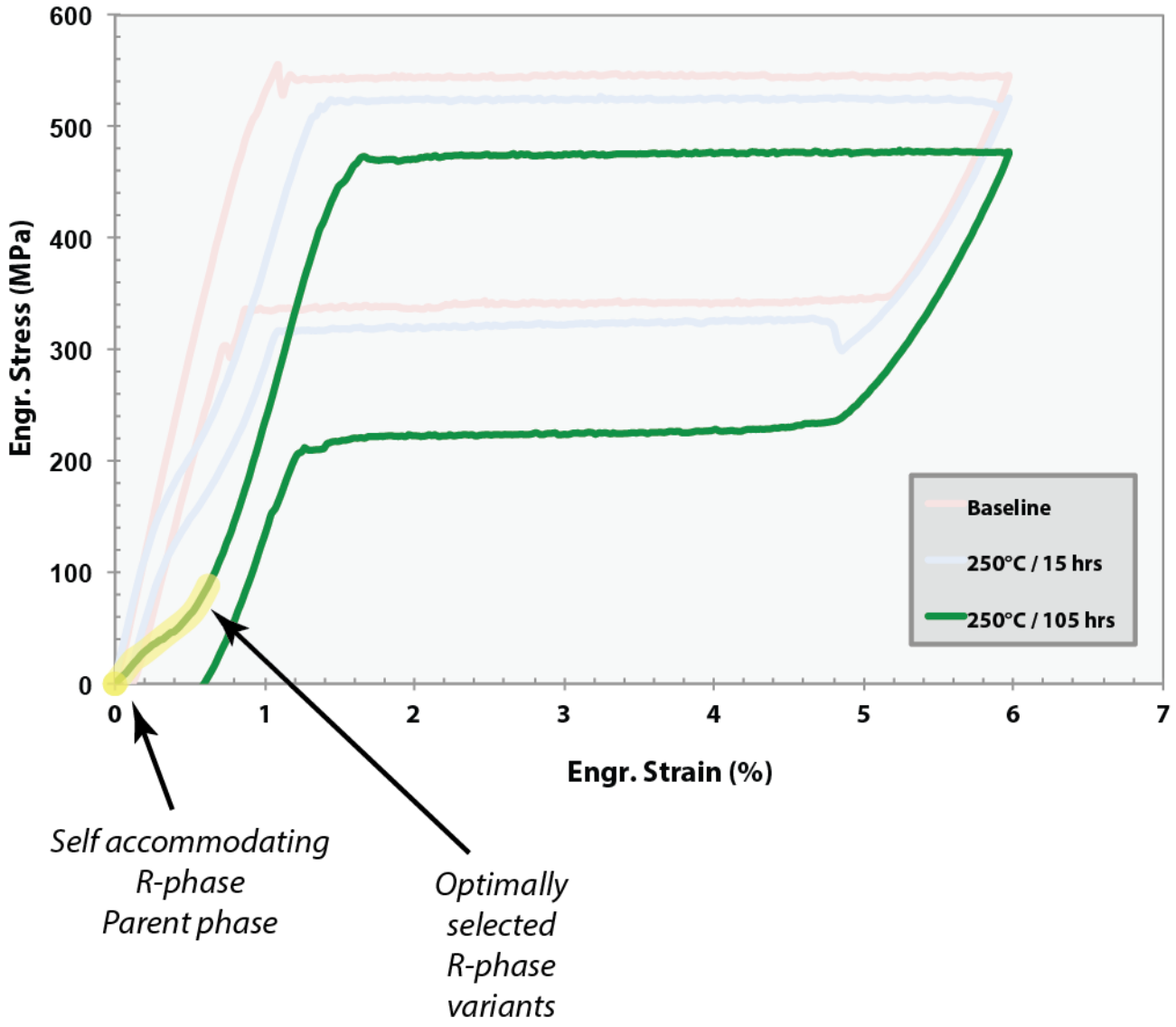

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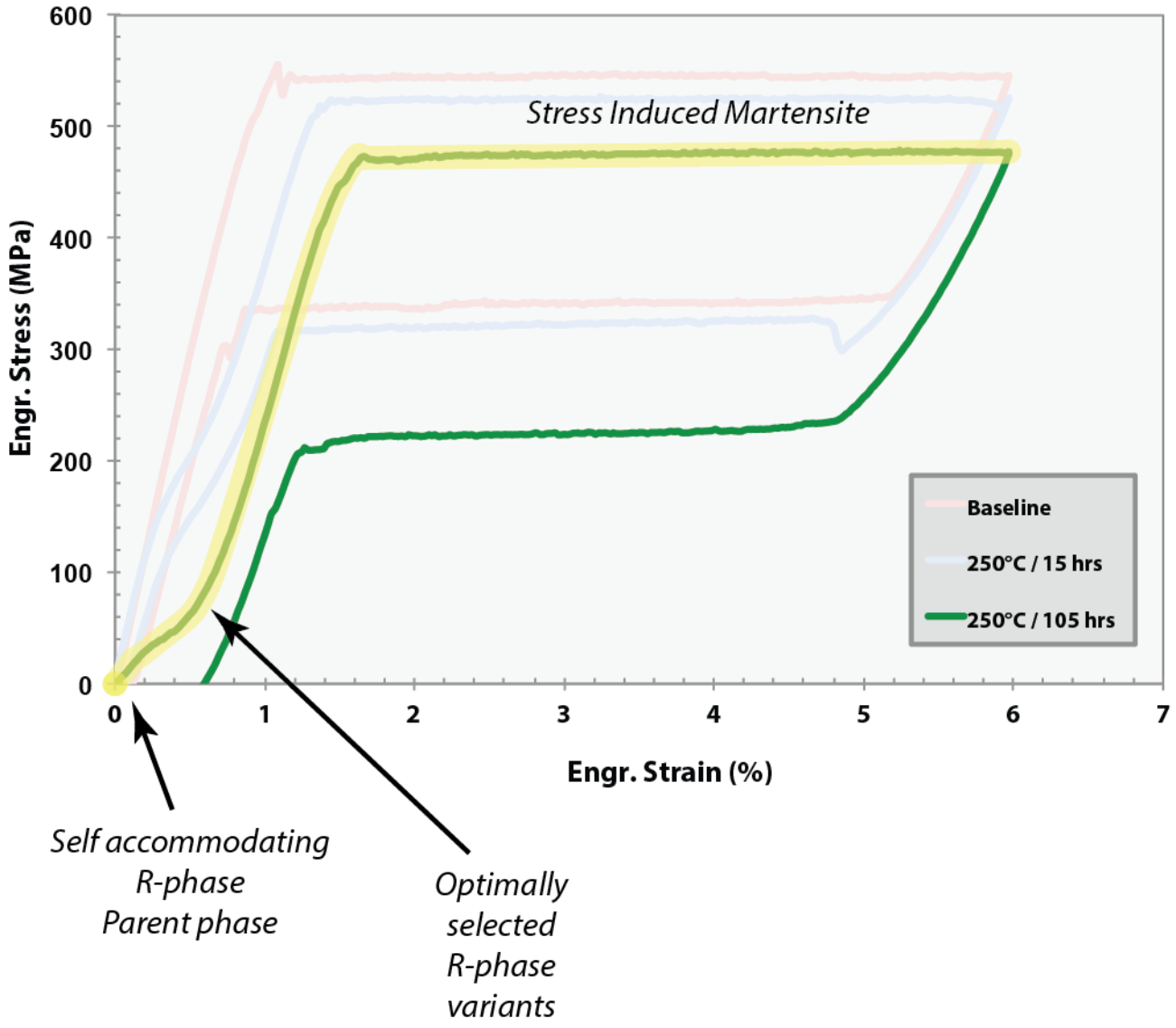

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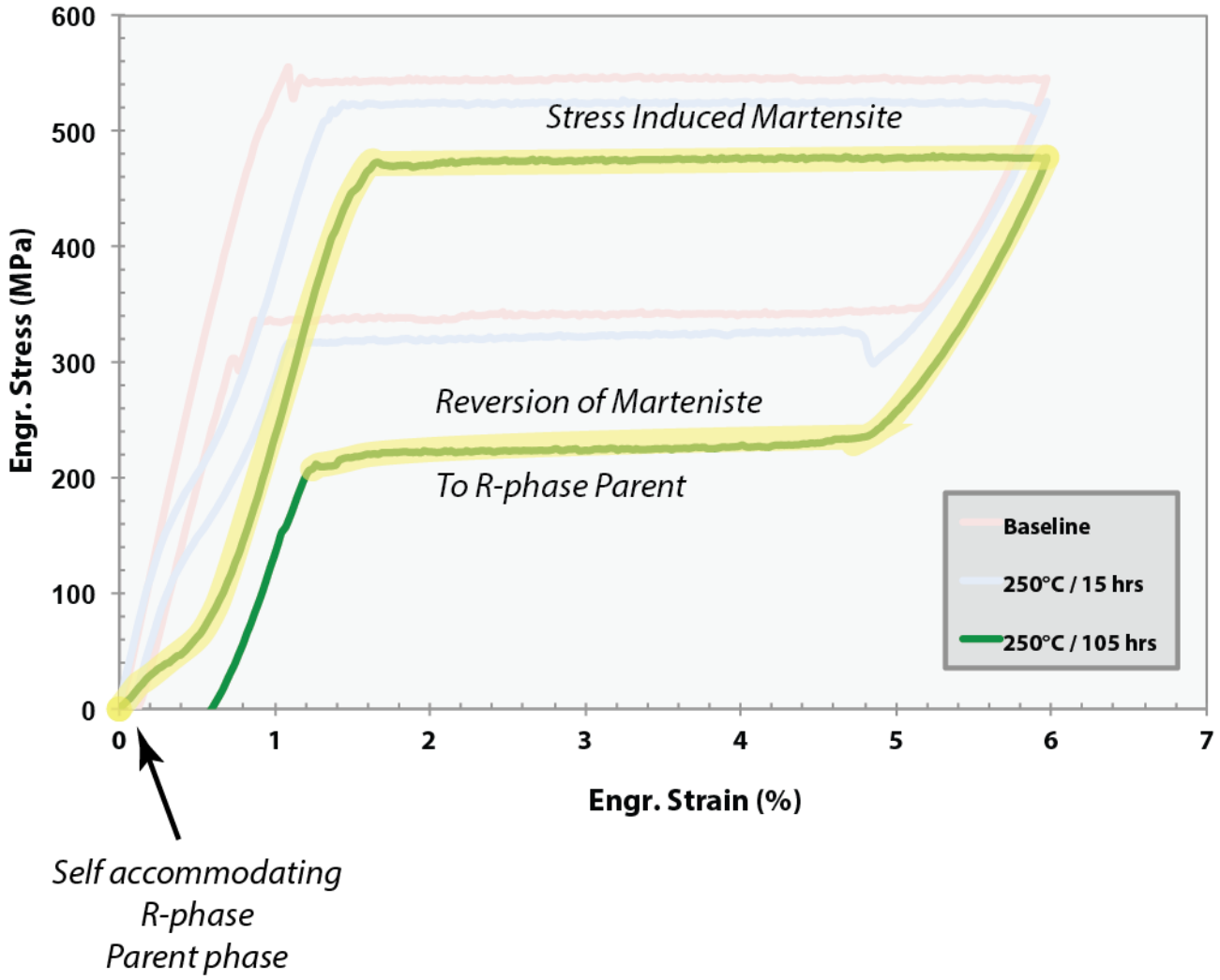

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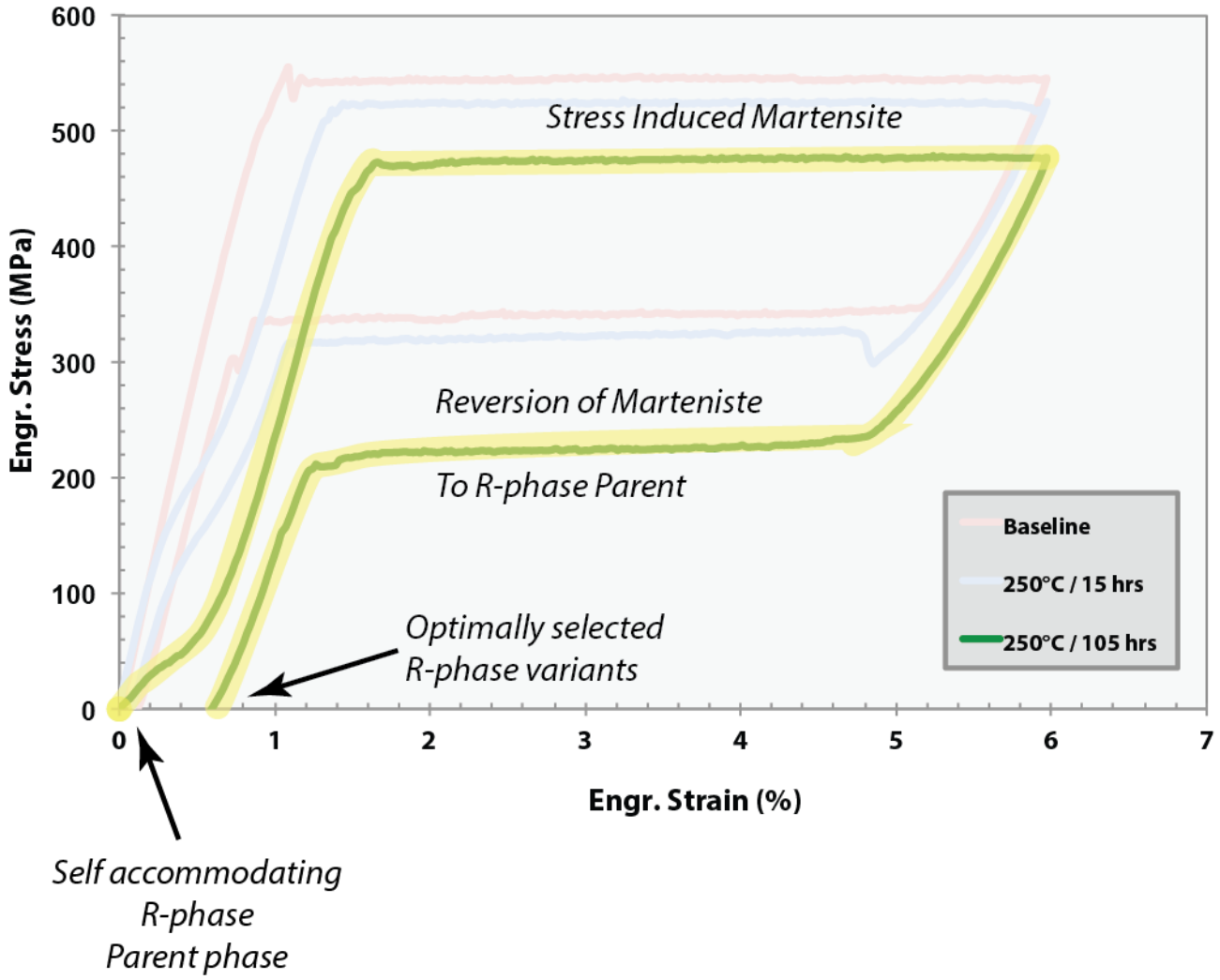
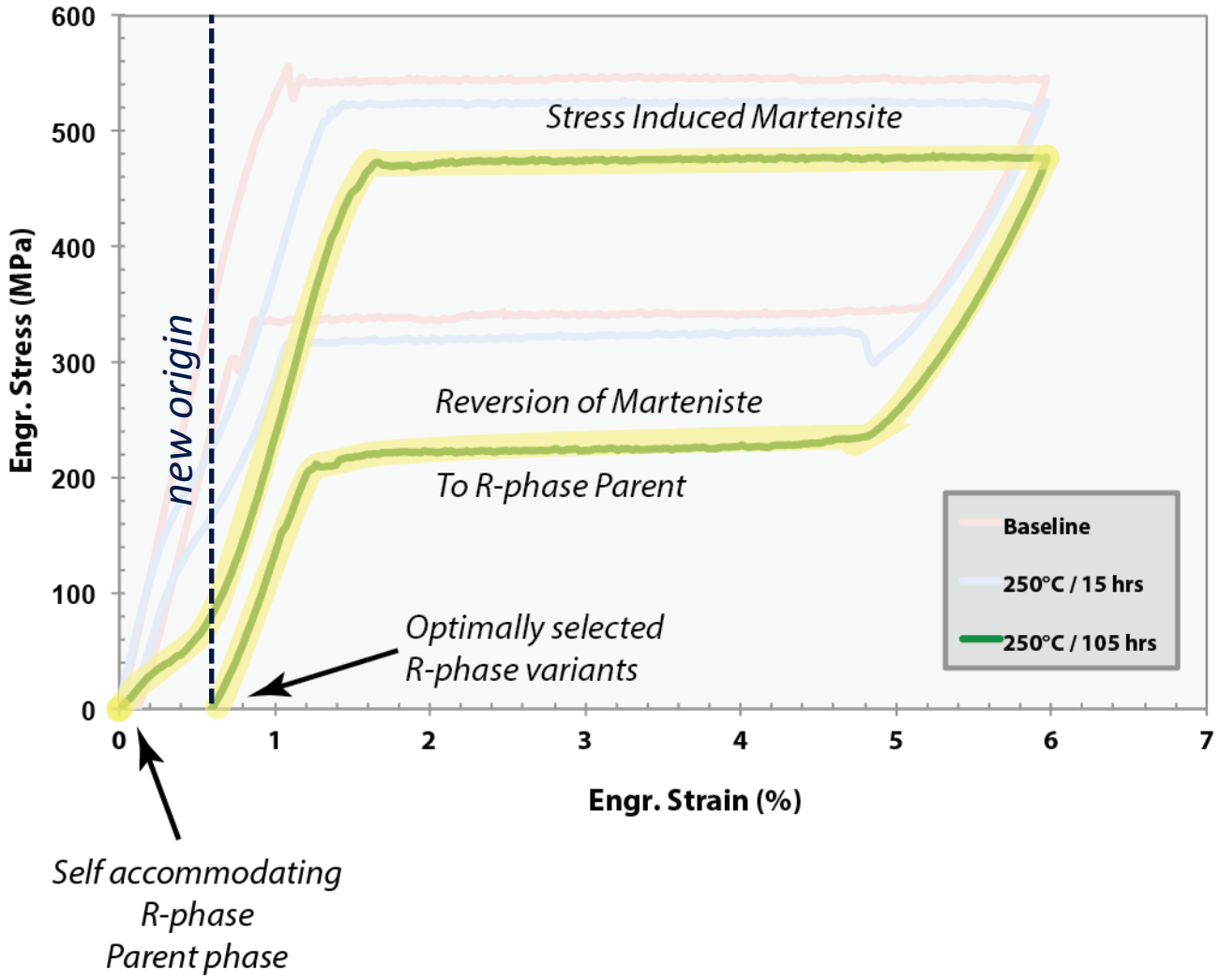
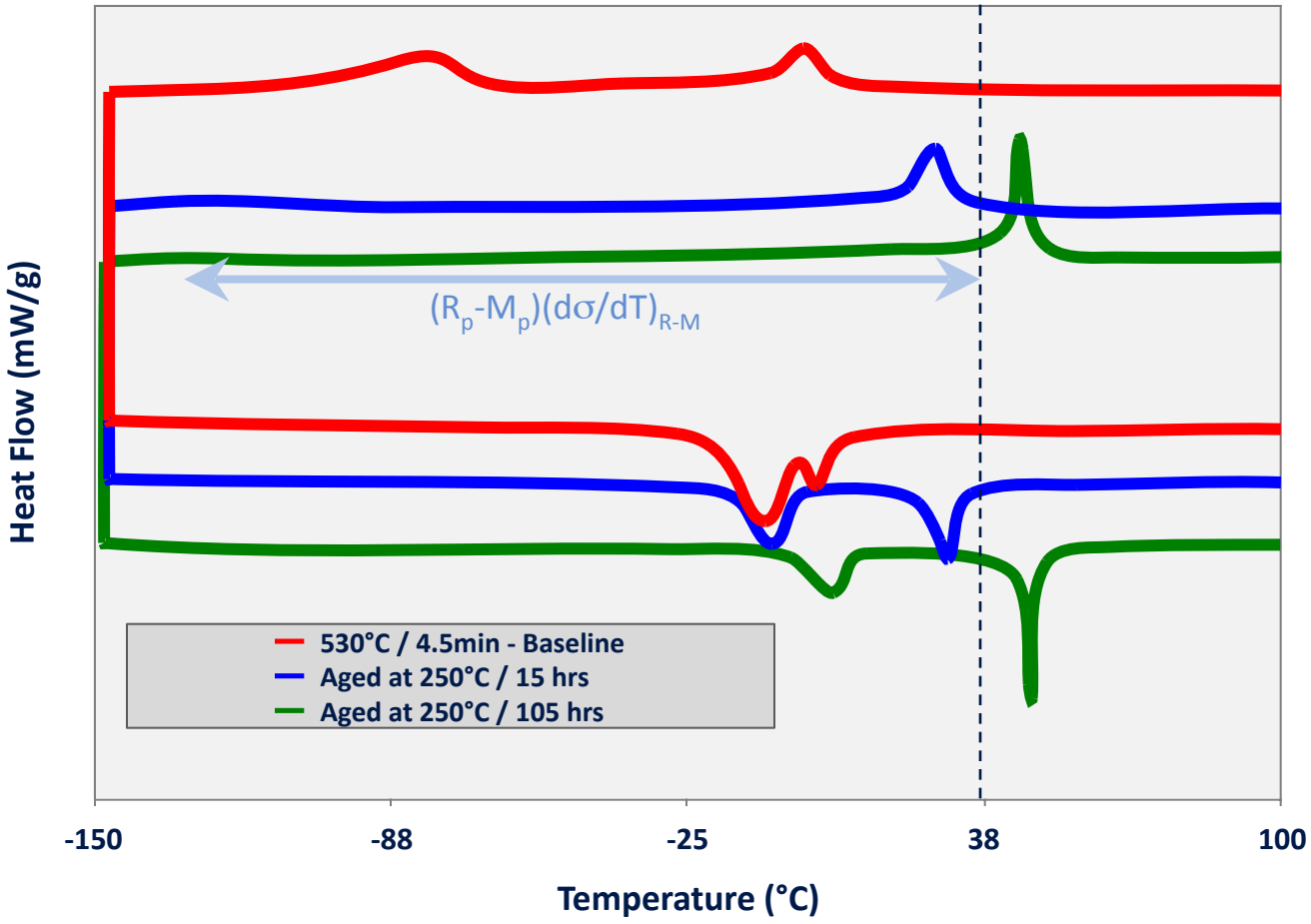


Who cares:

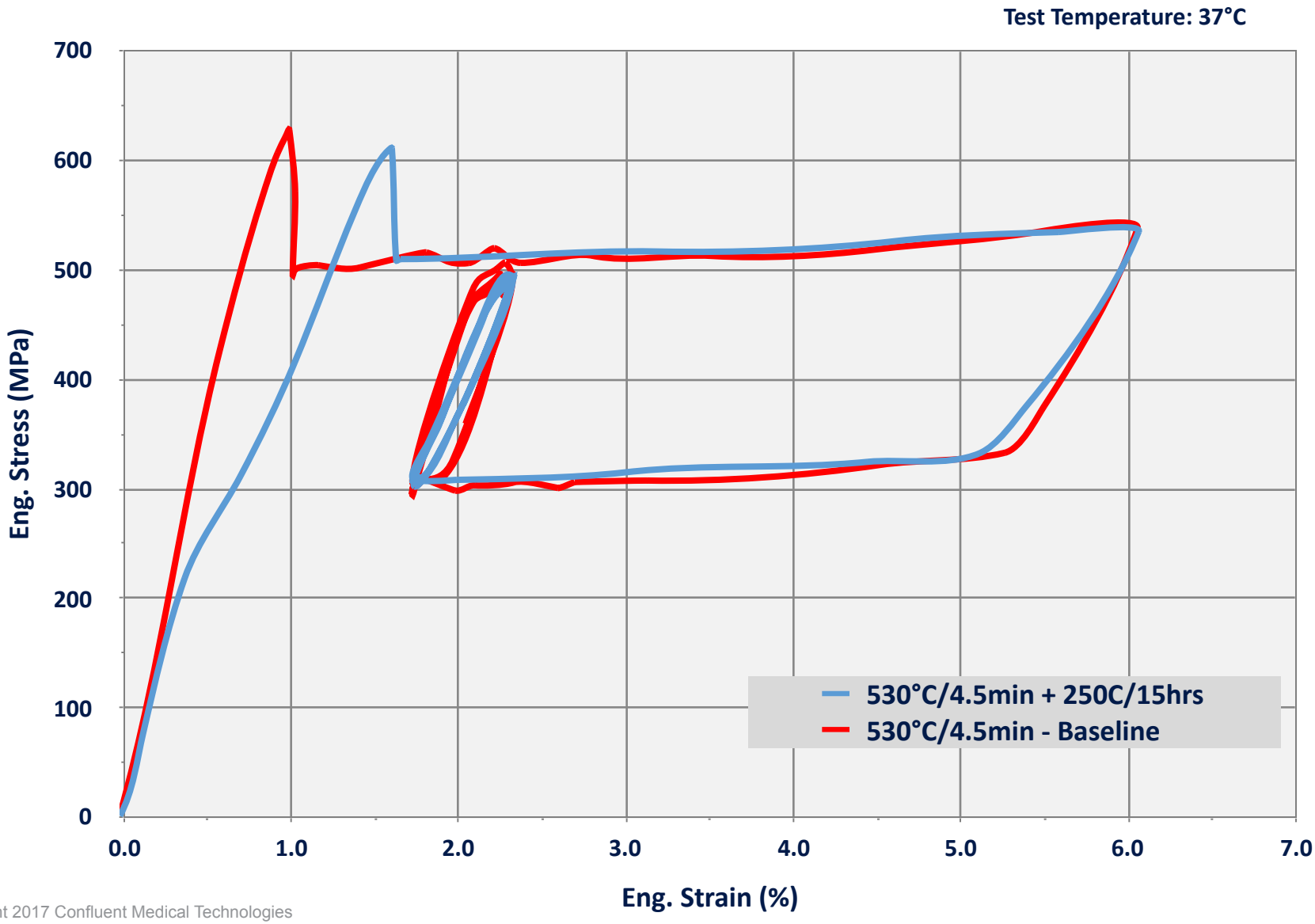
1. Move to move origin, so plateau shortens by about 0.5%



Who cares:
2. dσ/dT decreases, extending the superelastic “window”



Who cares:
3. Duty cycle is more compliant



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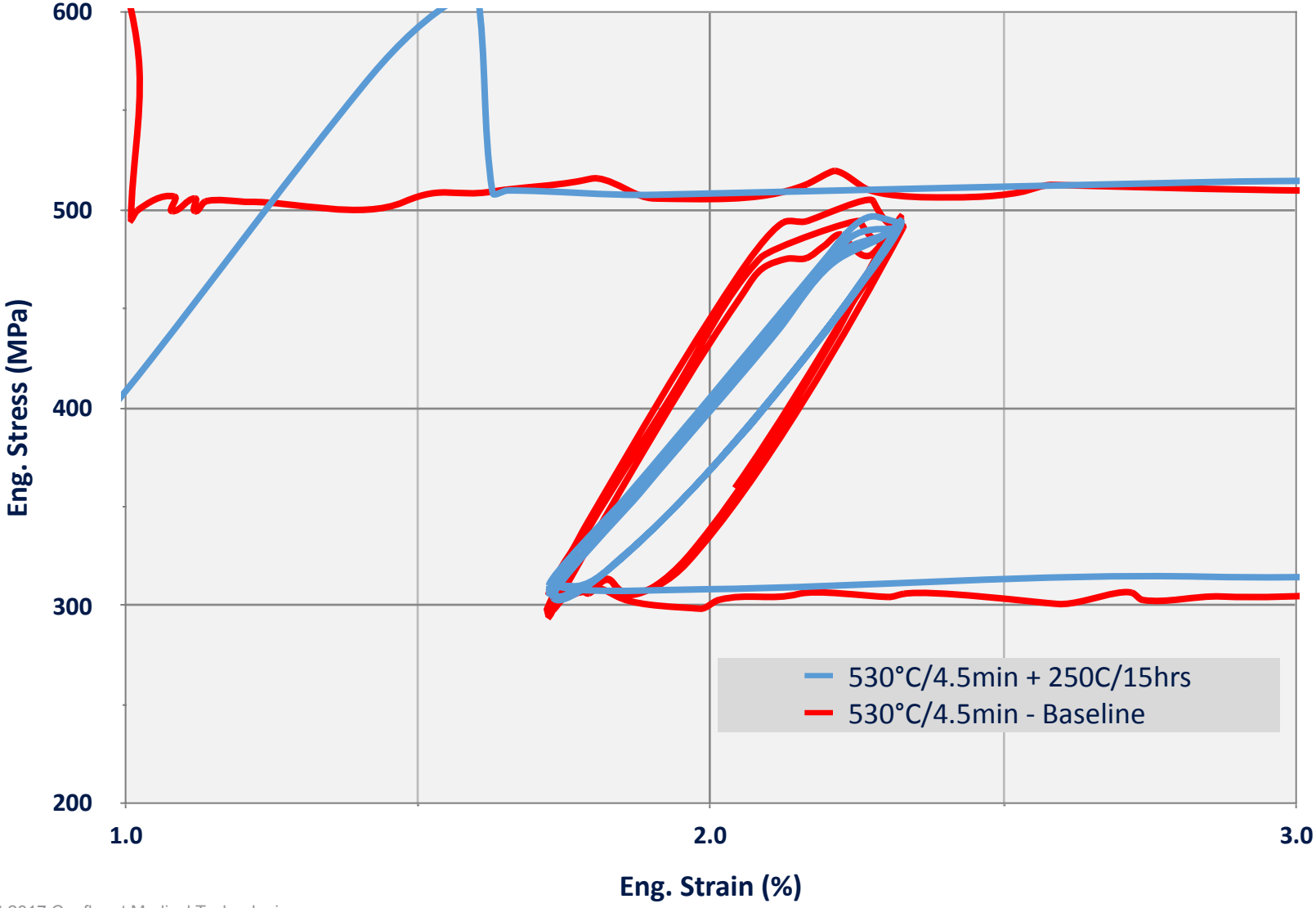
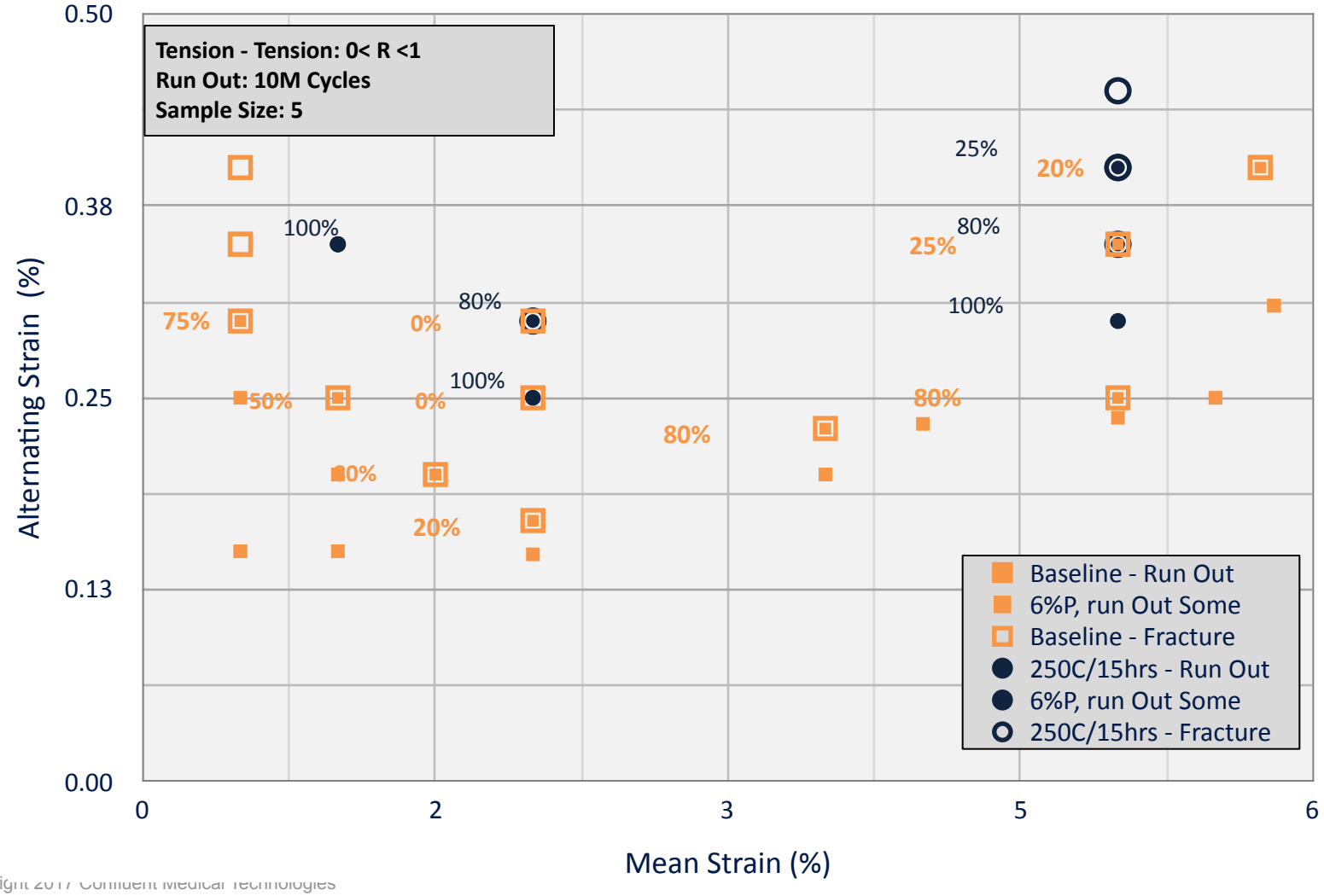


Who cares:
4. Durability is improved (?)



Conclusions

- "Excellent superelasticity" can occur well below A_f, eliminating Austenite from our duty cycle.
- Employing the R-phase as the parent phase opens unexplored horizons with potentially useful properties.
- More work to be done to determine the pro's and con's, including:
  - Examining the R-phase modulus and
  - The details of the R-M interface (λ_2)
  - Better understanding the net effect on durability

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