



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.

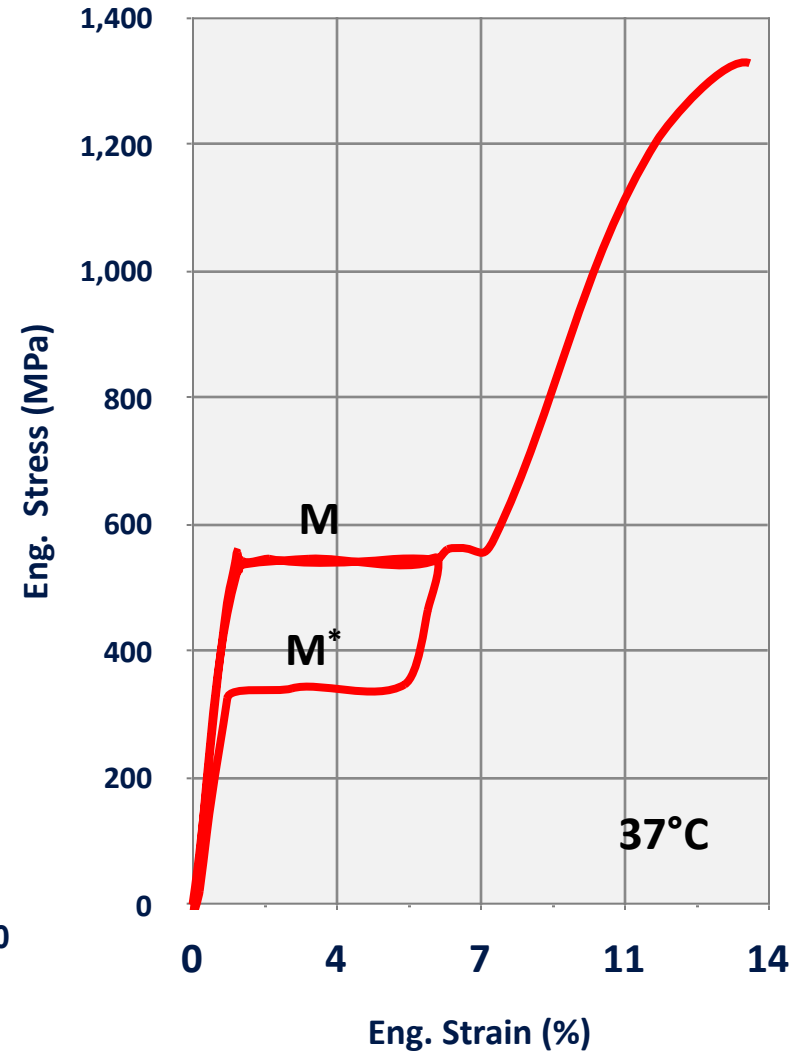
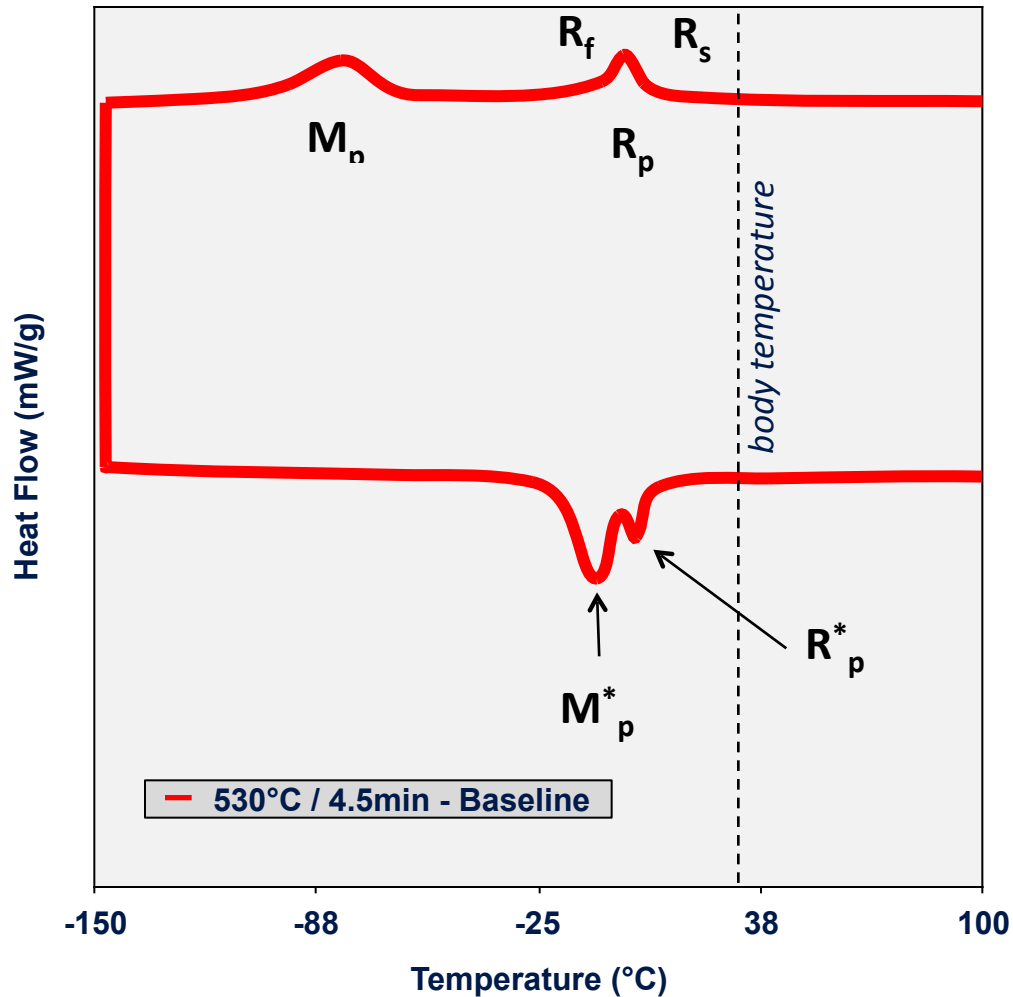
But in fact:

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

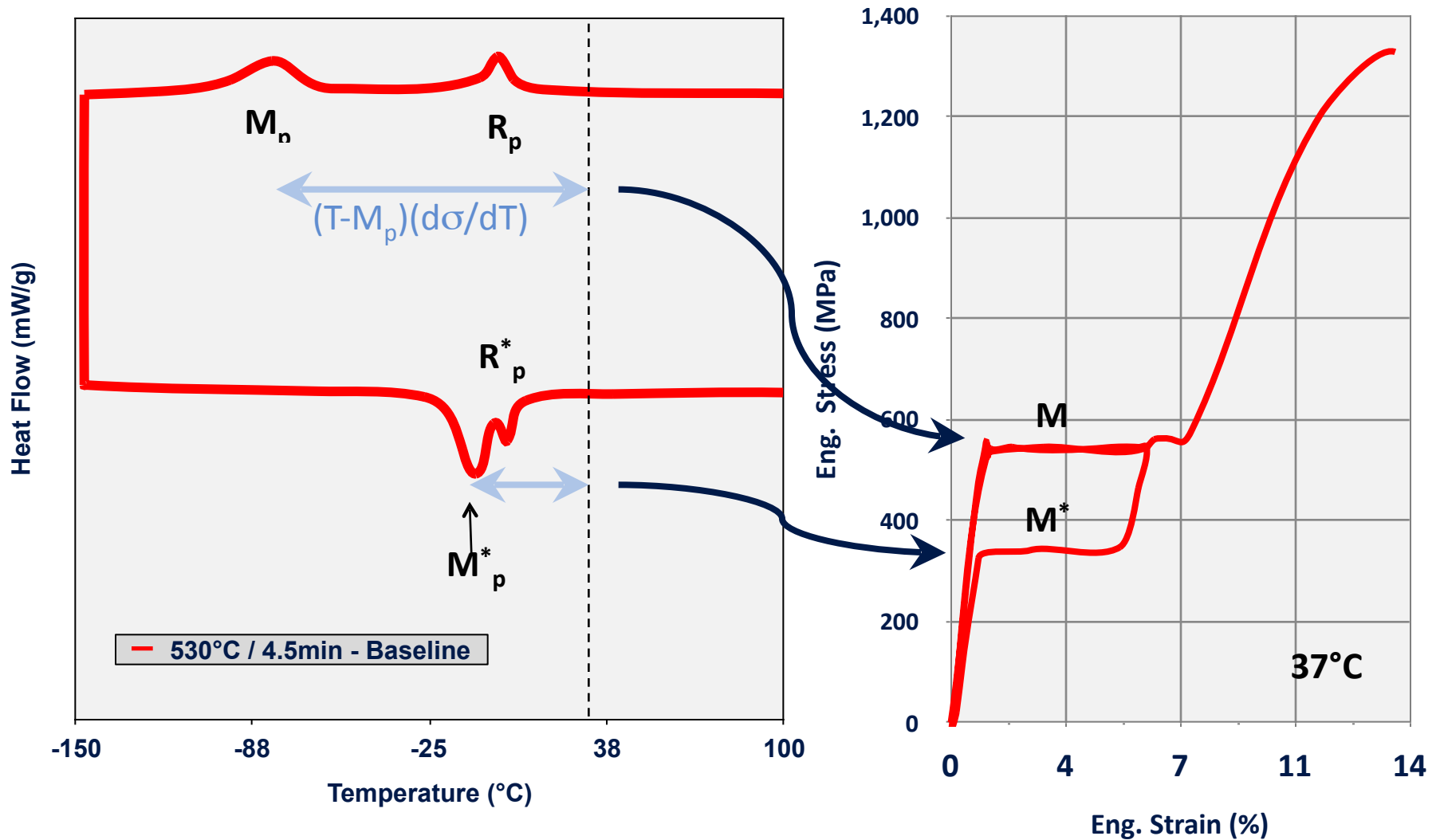
How does this affect superelastic properties?

Traditional superelastic material

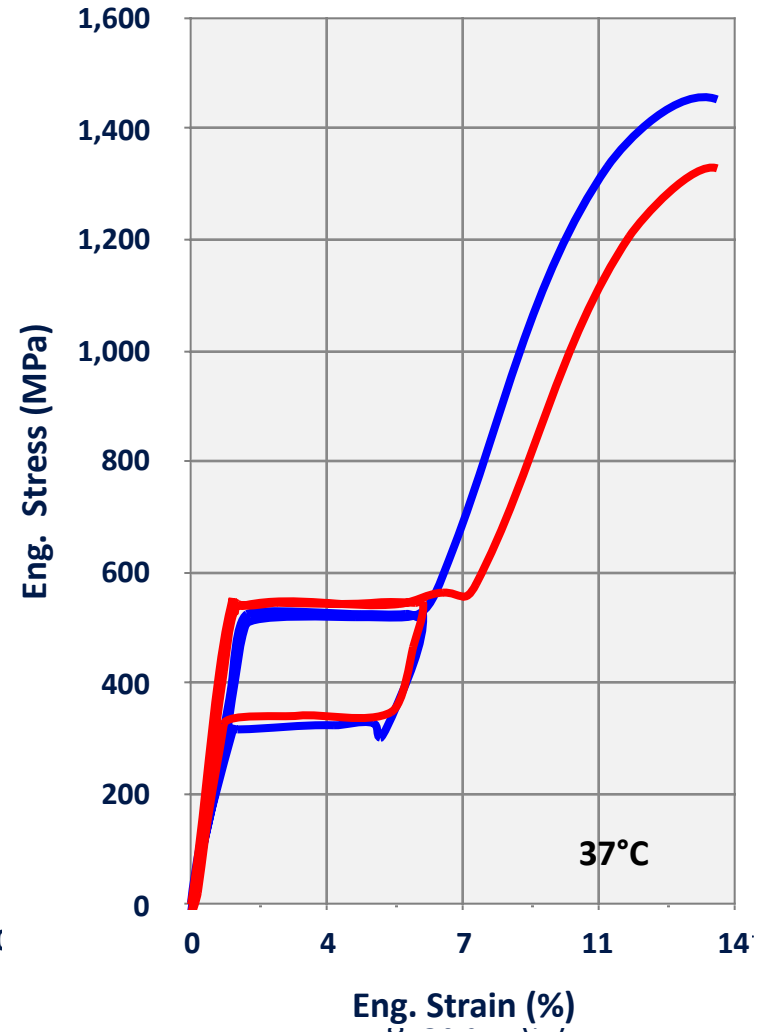
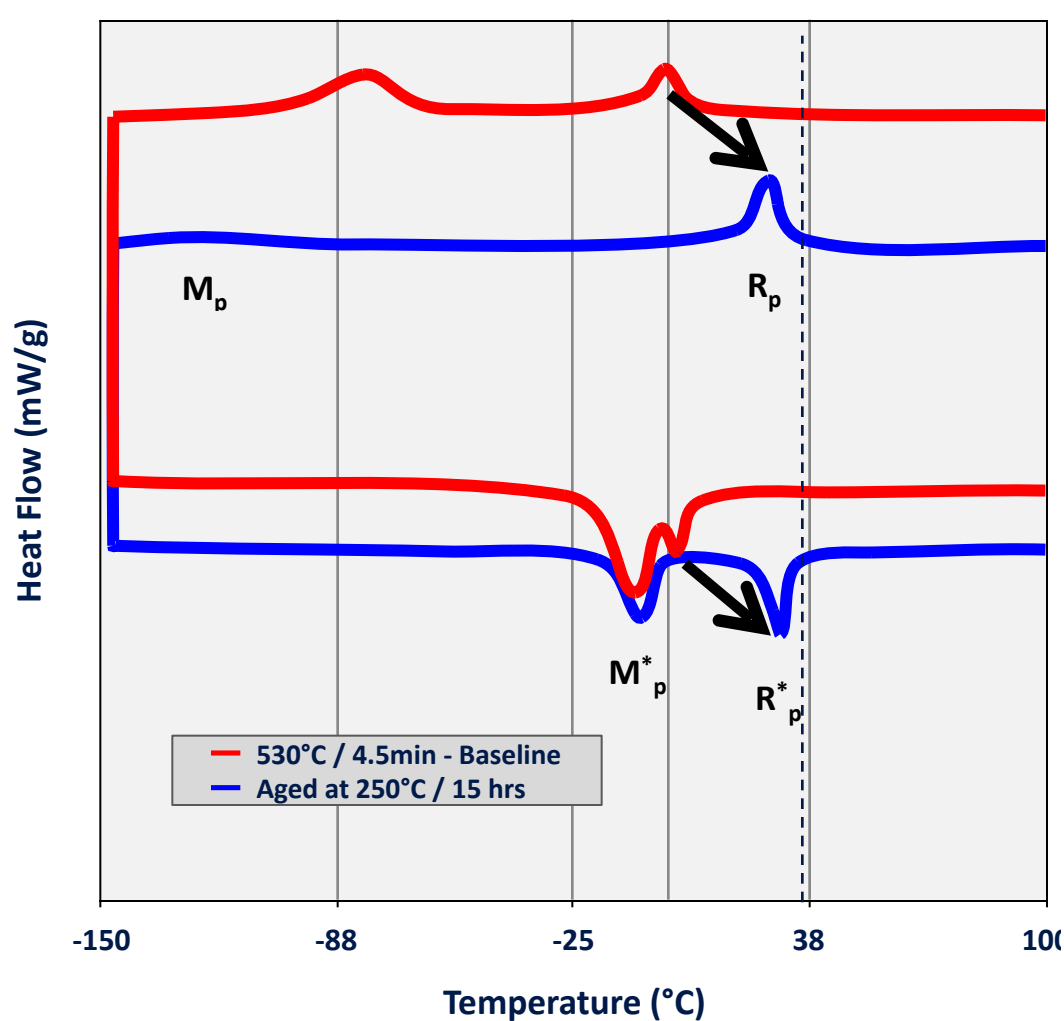
R is not stress induced



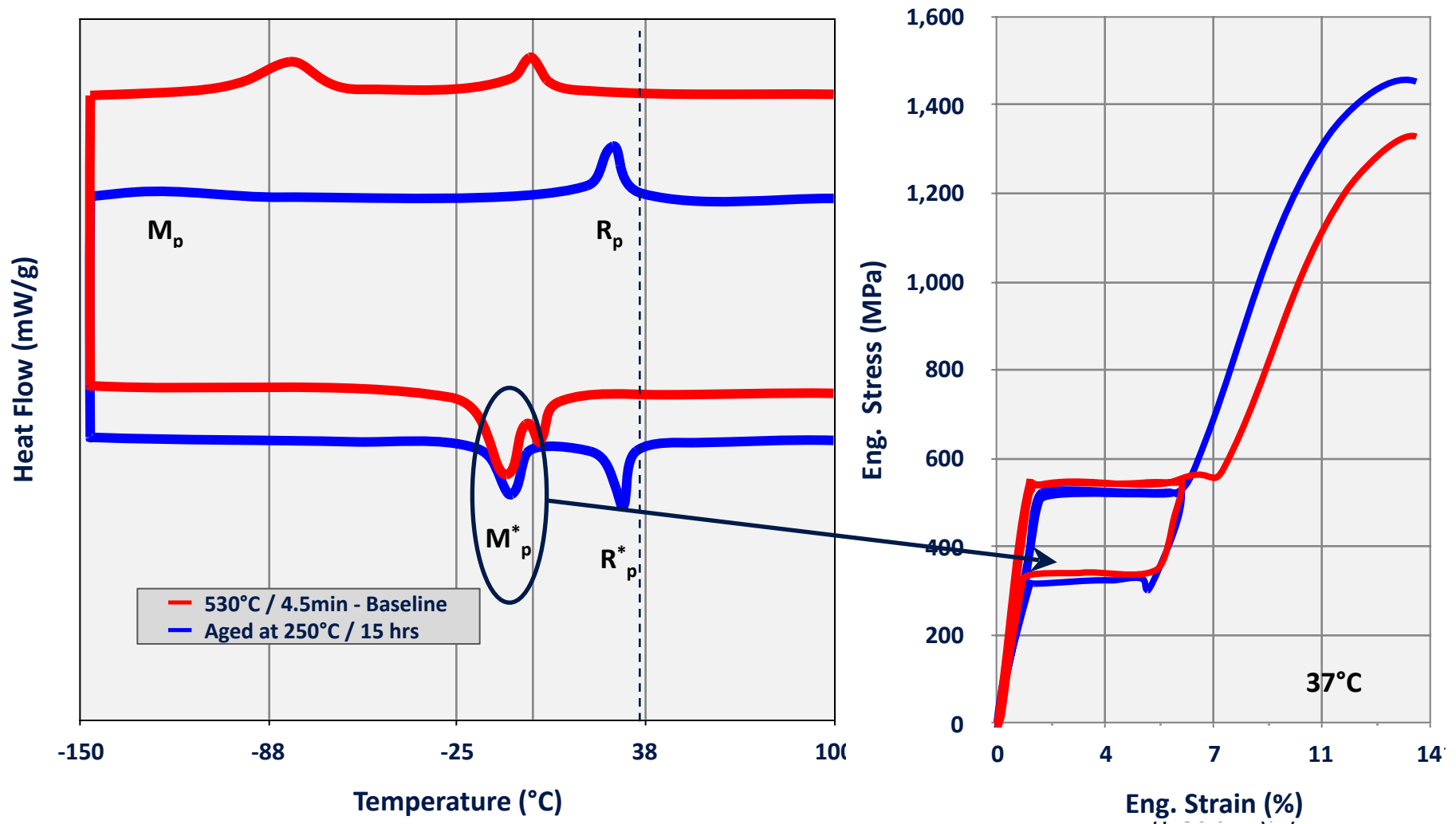
Traditional superelastic material:
M and M* reflect the upper and lower plateau stresses



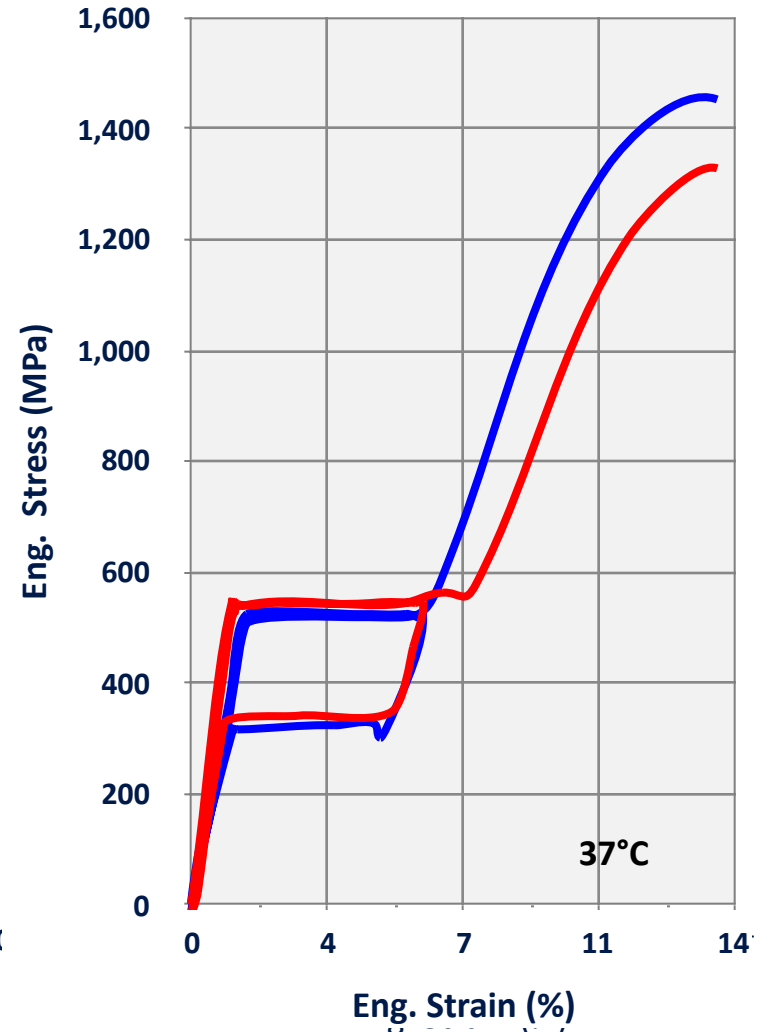
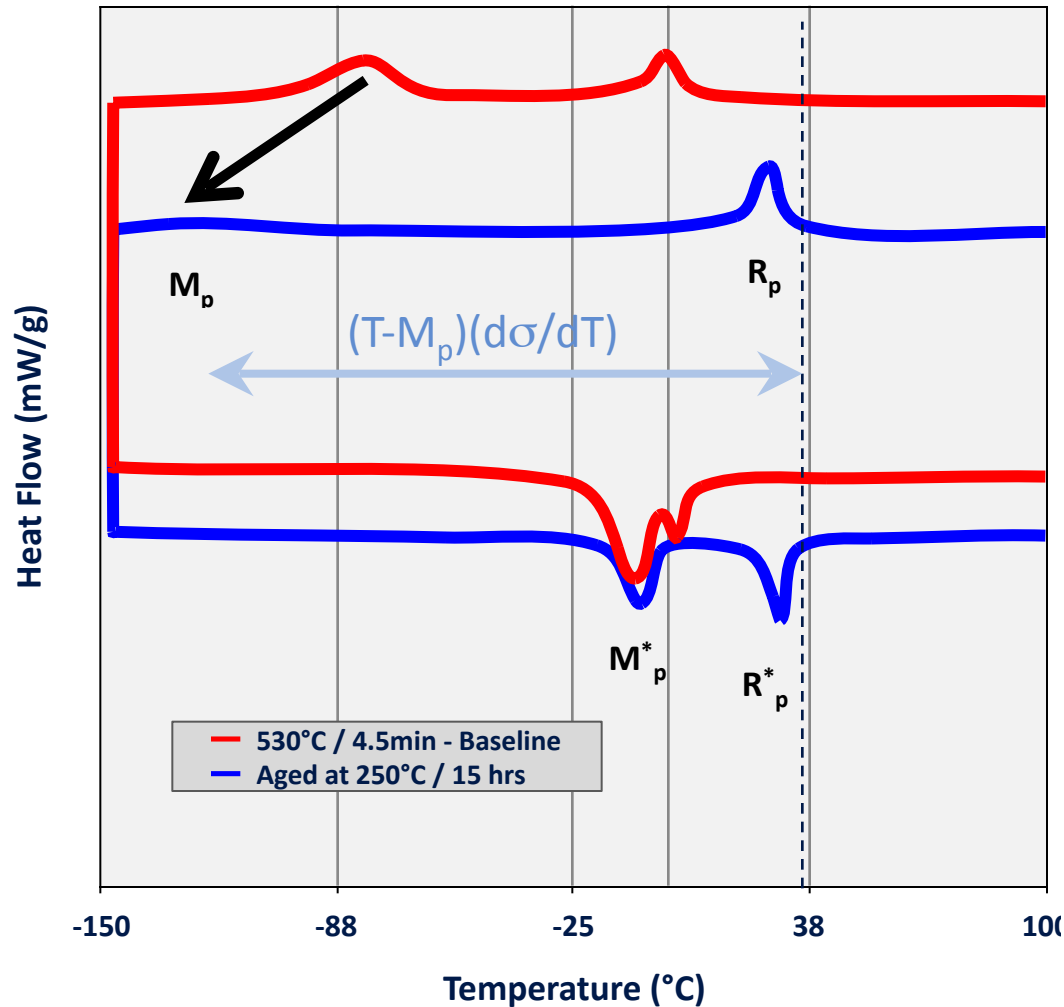
Low temperature aging stabilizes the R-phase



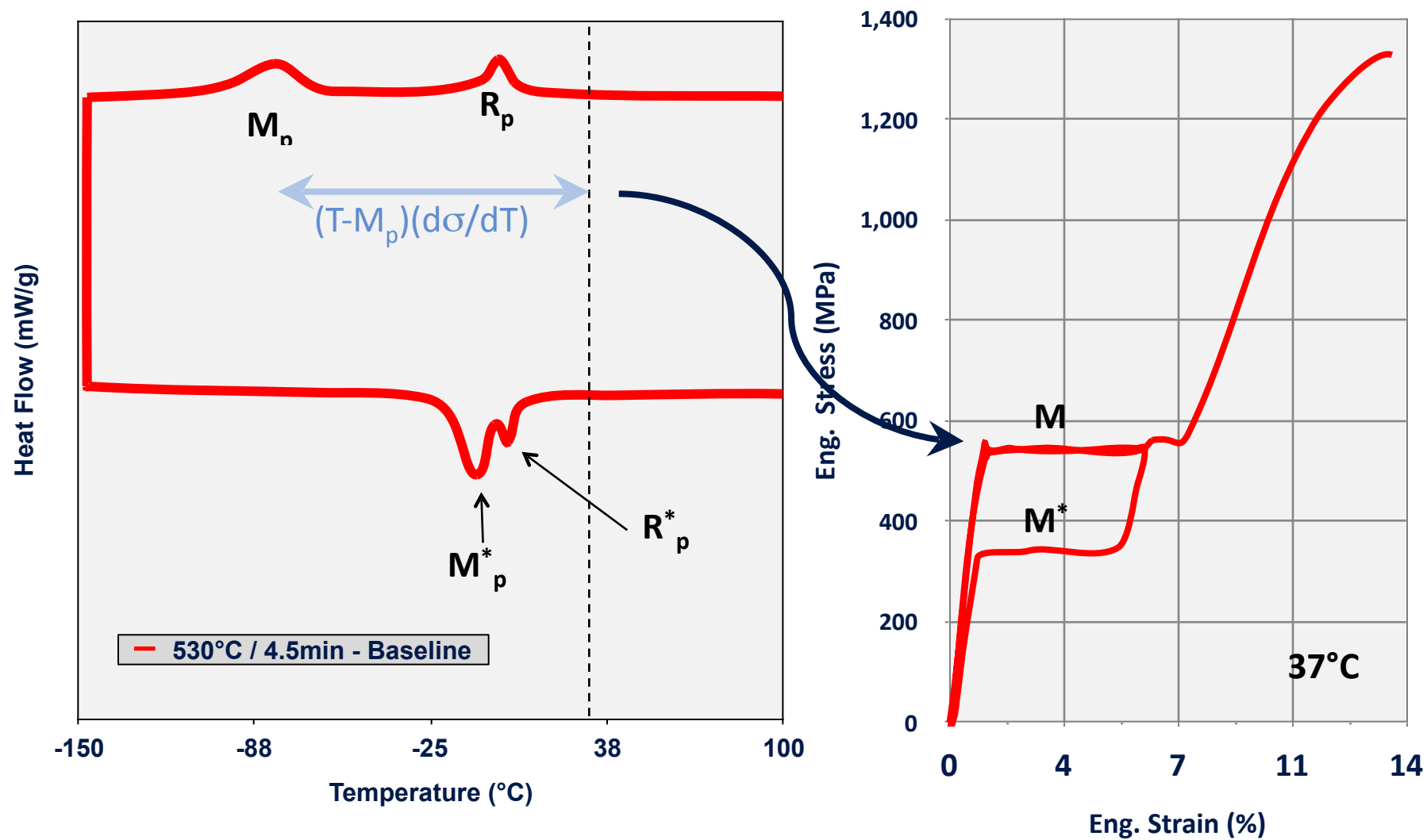
Low temperature aging does not move M^*



Low temperature aging suppresses M but leaves UPS unaffected?

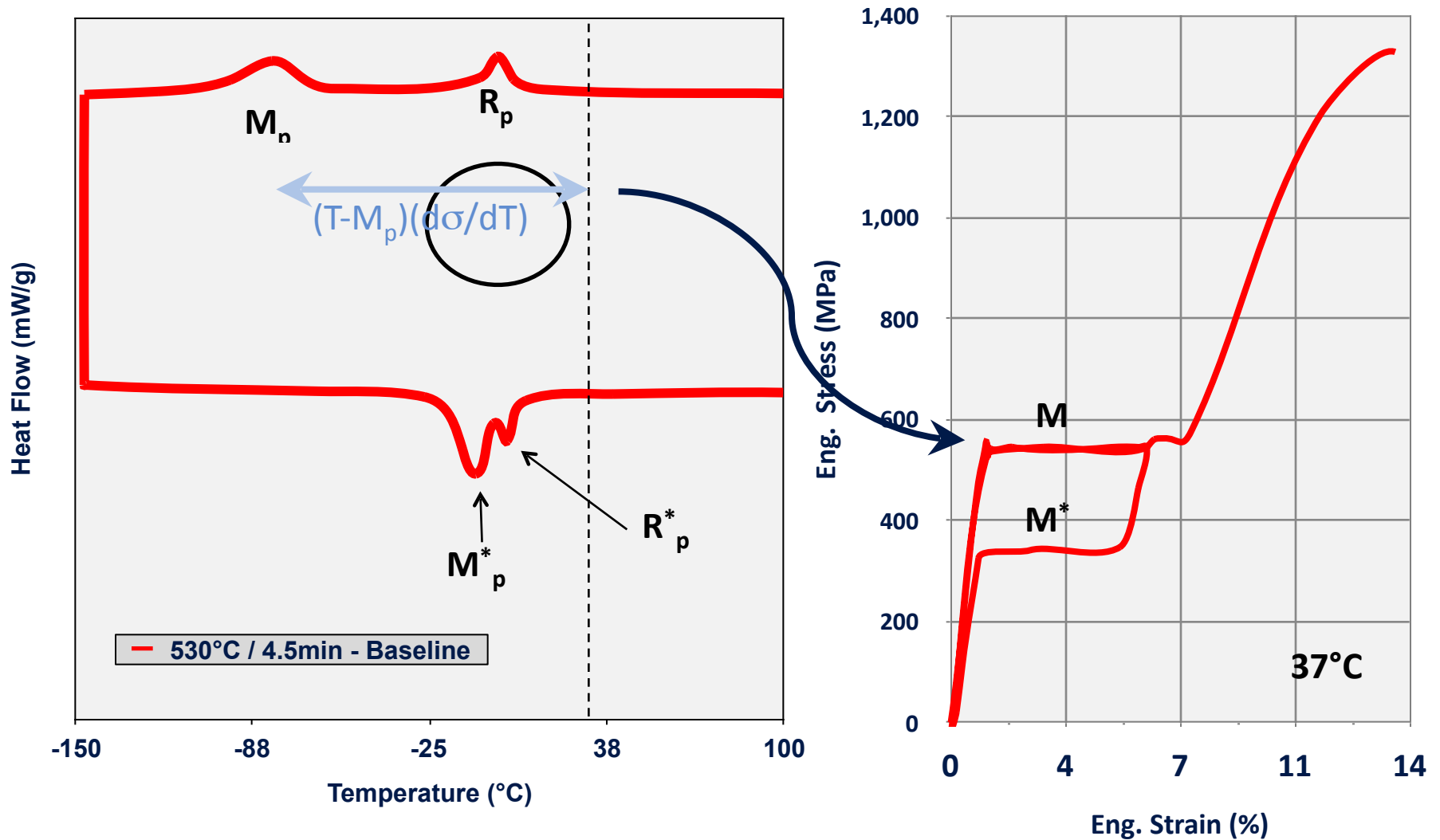


Traditional superelastic material

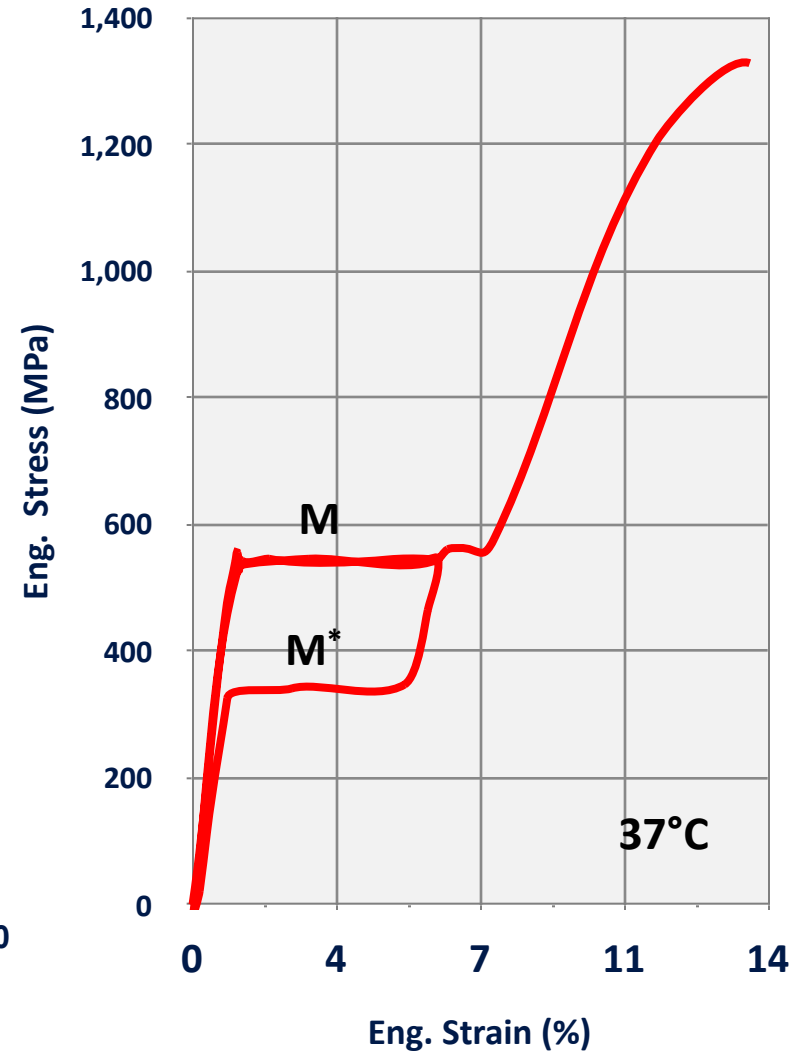
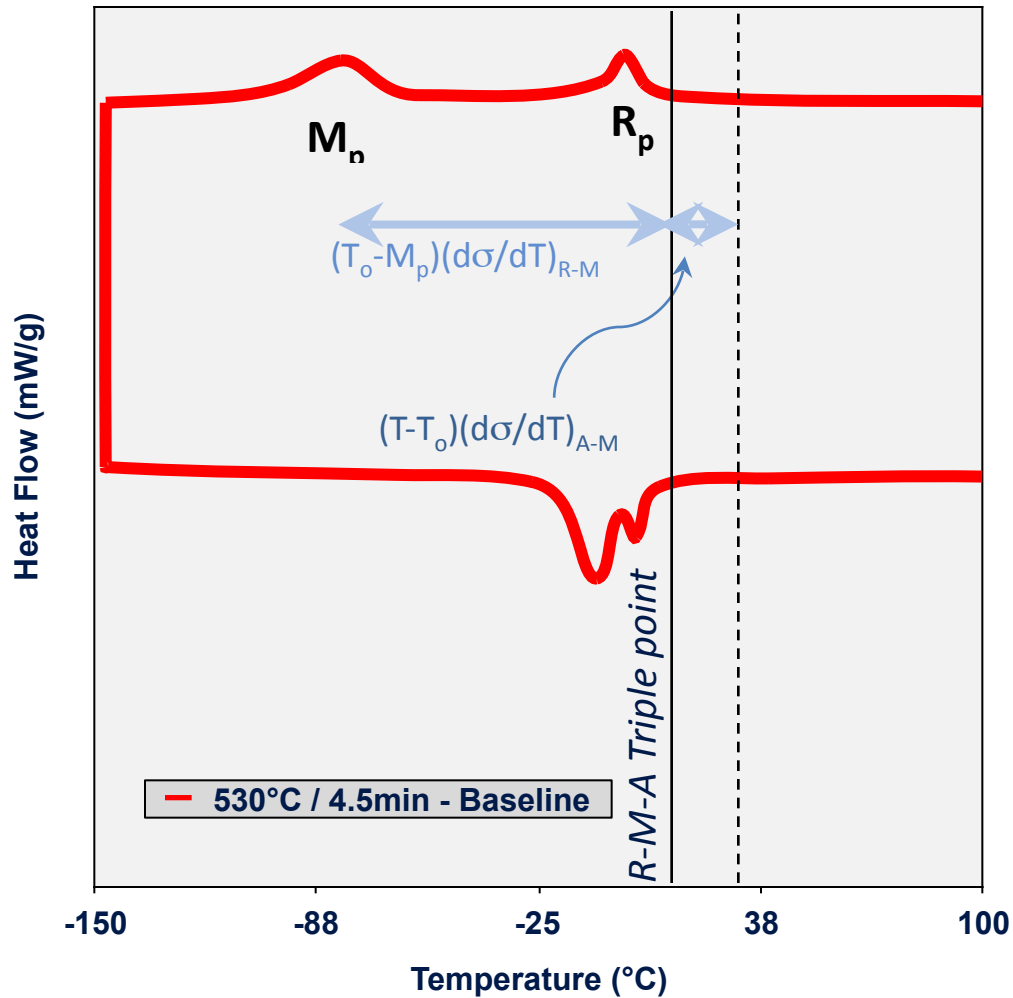


Traditional superelastic material

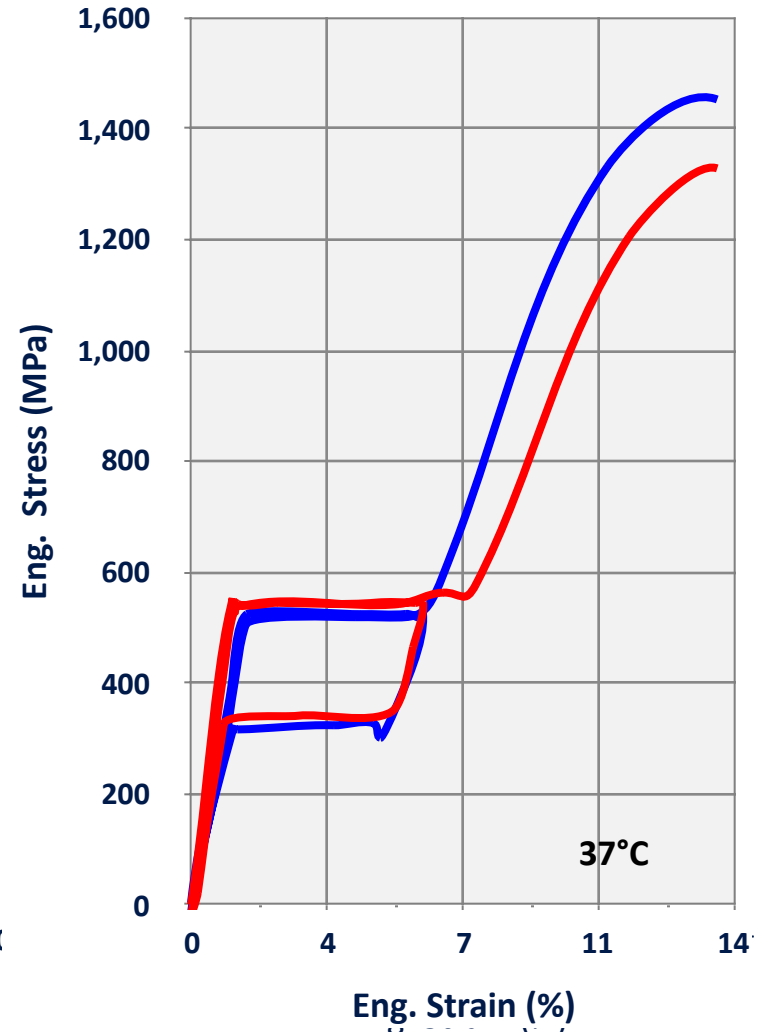
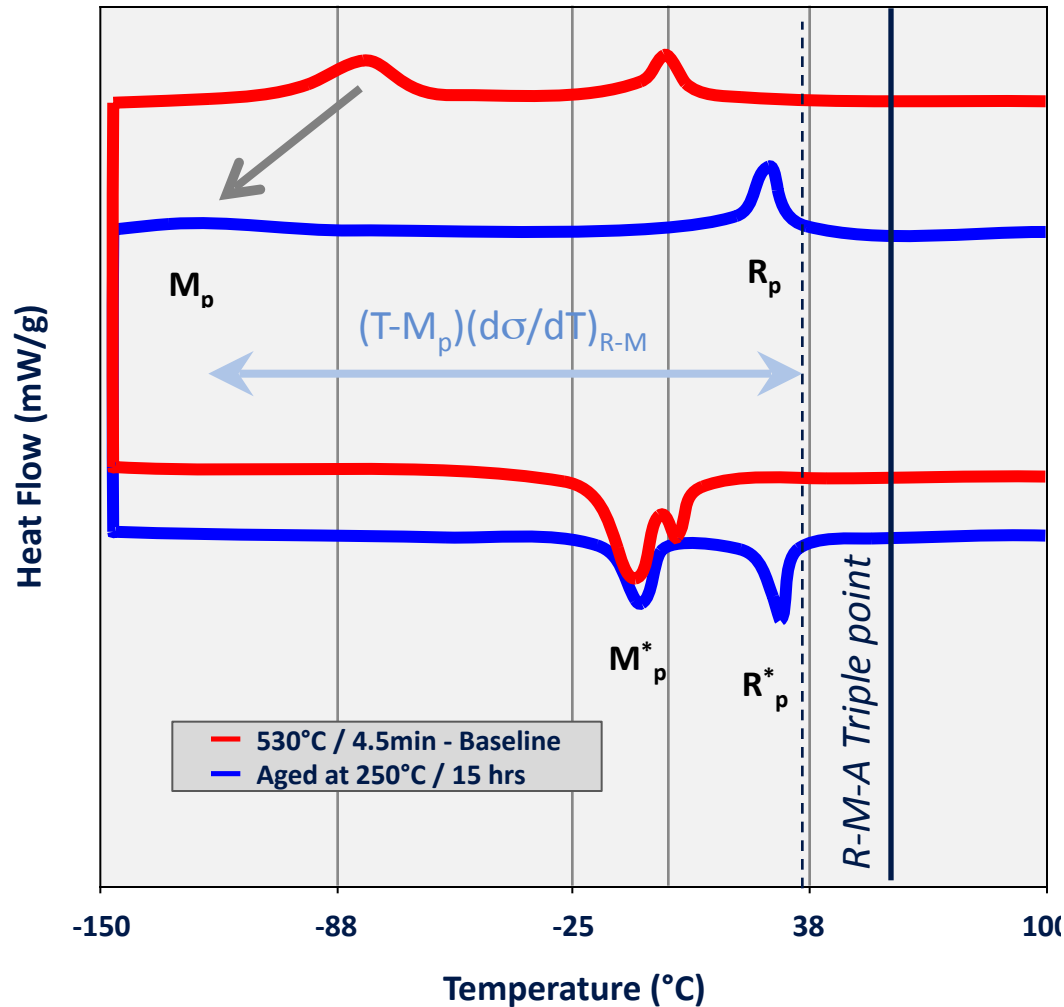
Which $d\sigma/dT$ is operative, A-R, A-M or R-M?



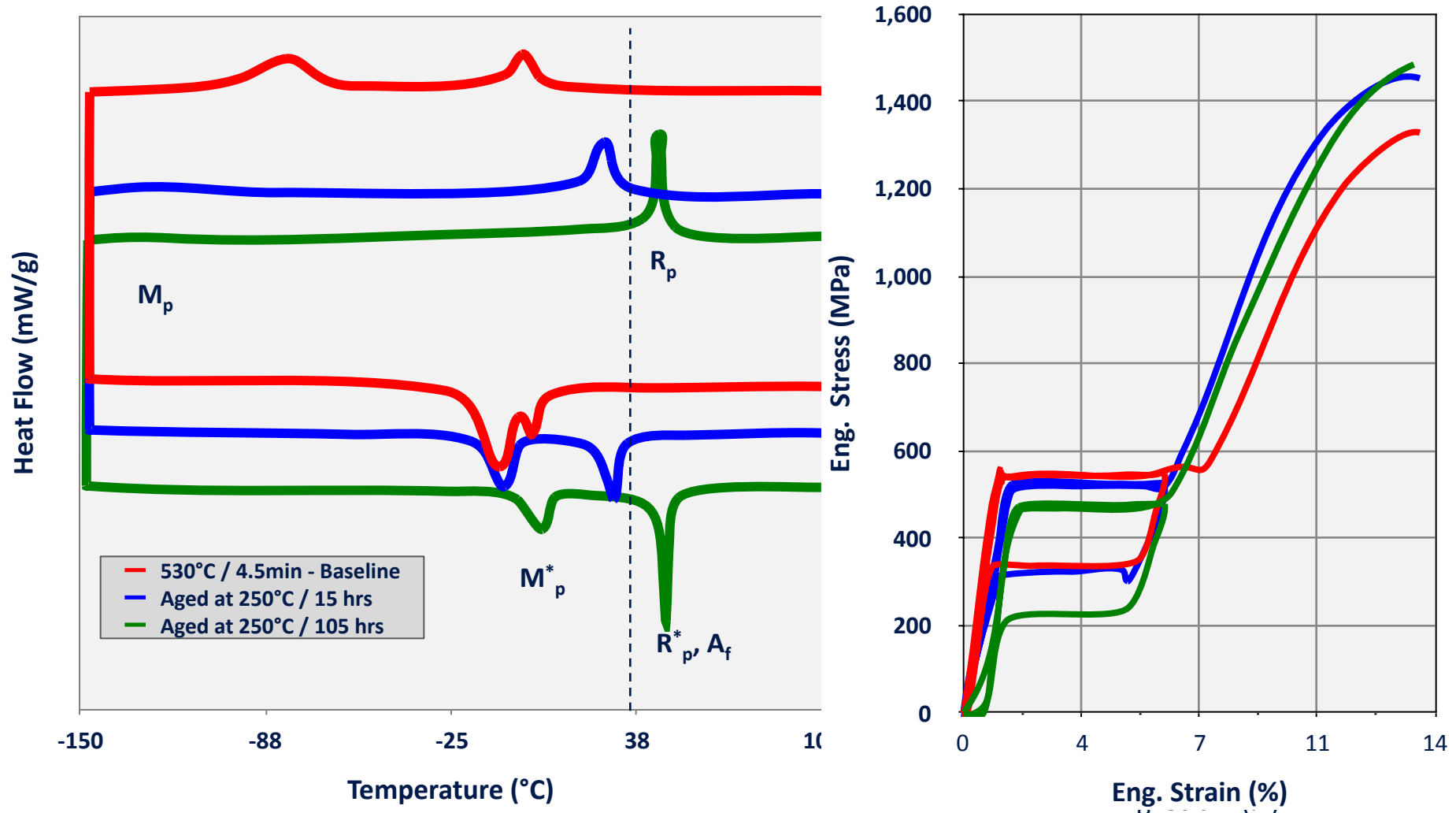
Traditional superelastic material



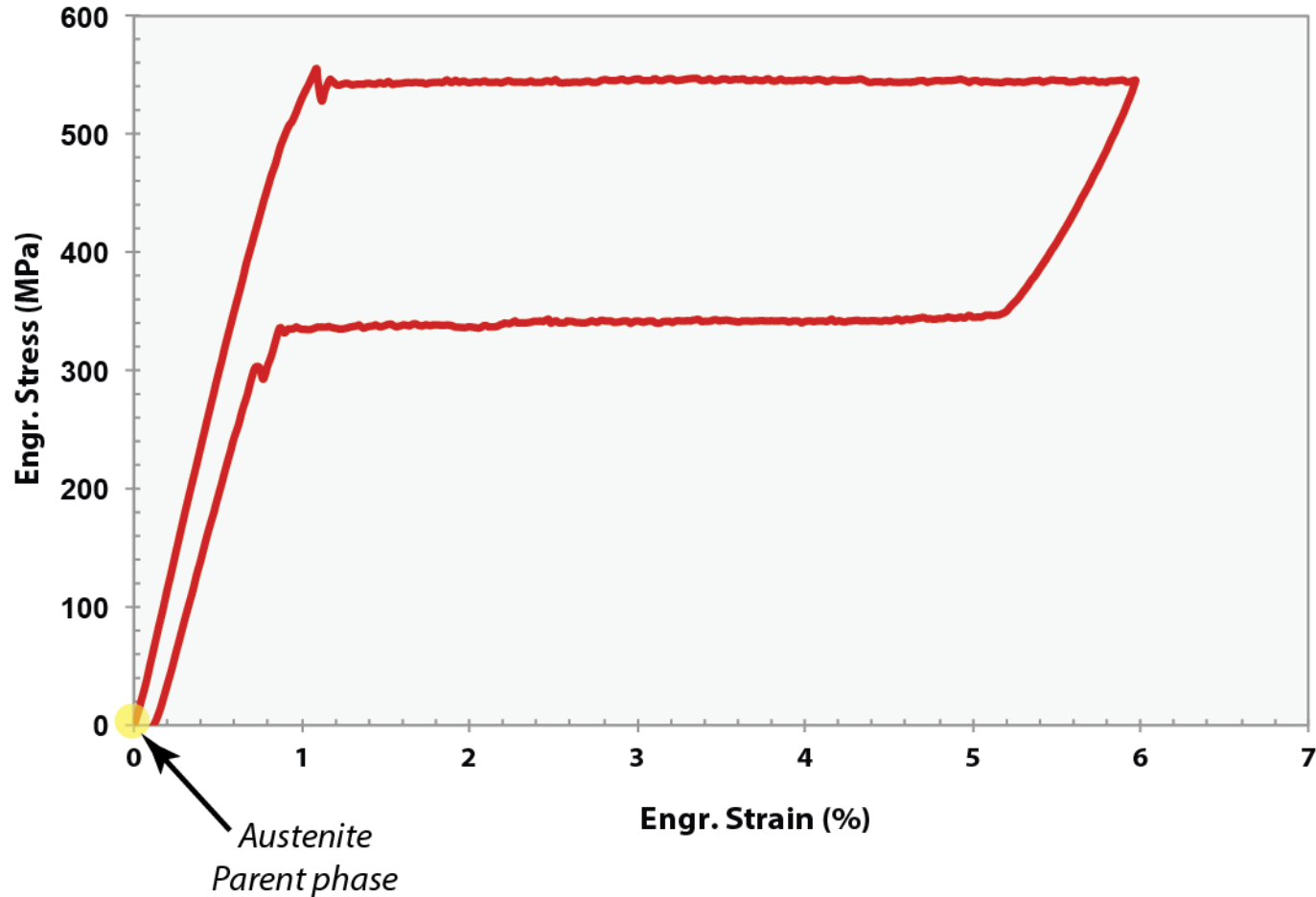
Low temperature aging decreases average $d\sigma/dT$
 T is now below the triple point



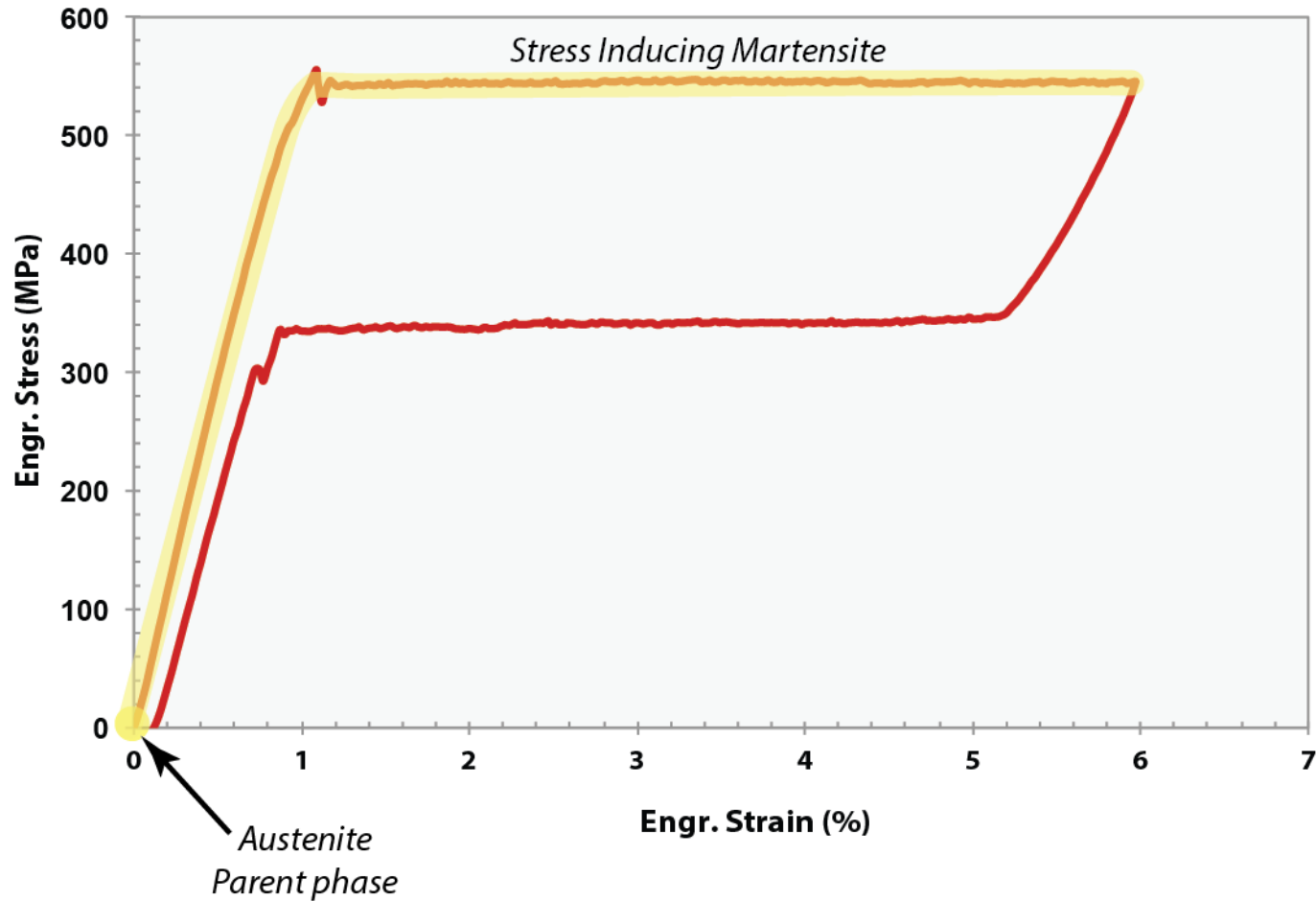
Further aging drives R_p^* (A_f) above 37°C
Austenite now plays no role in the superelastic process



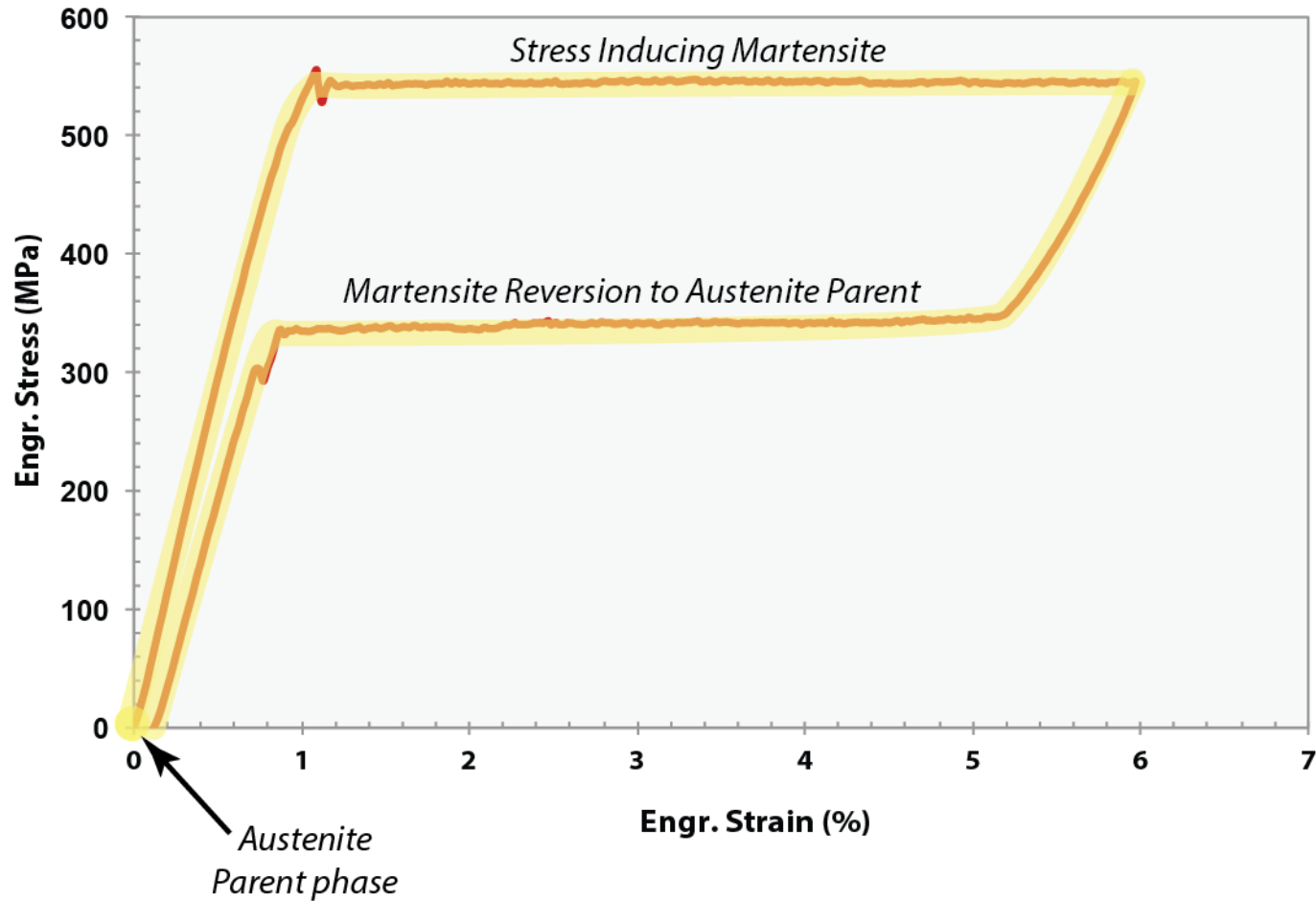
Scenario 1: A-M-A classical superelasticity (above the triple point):



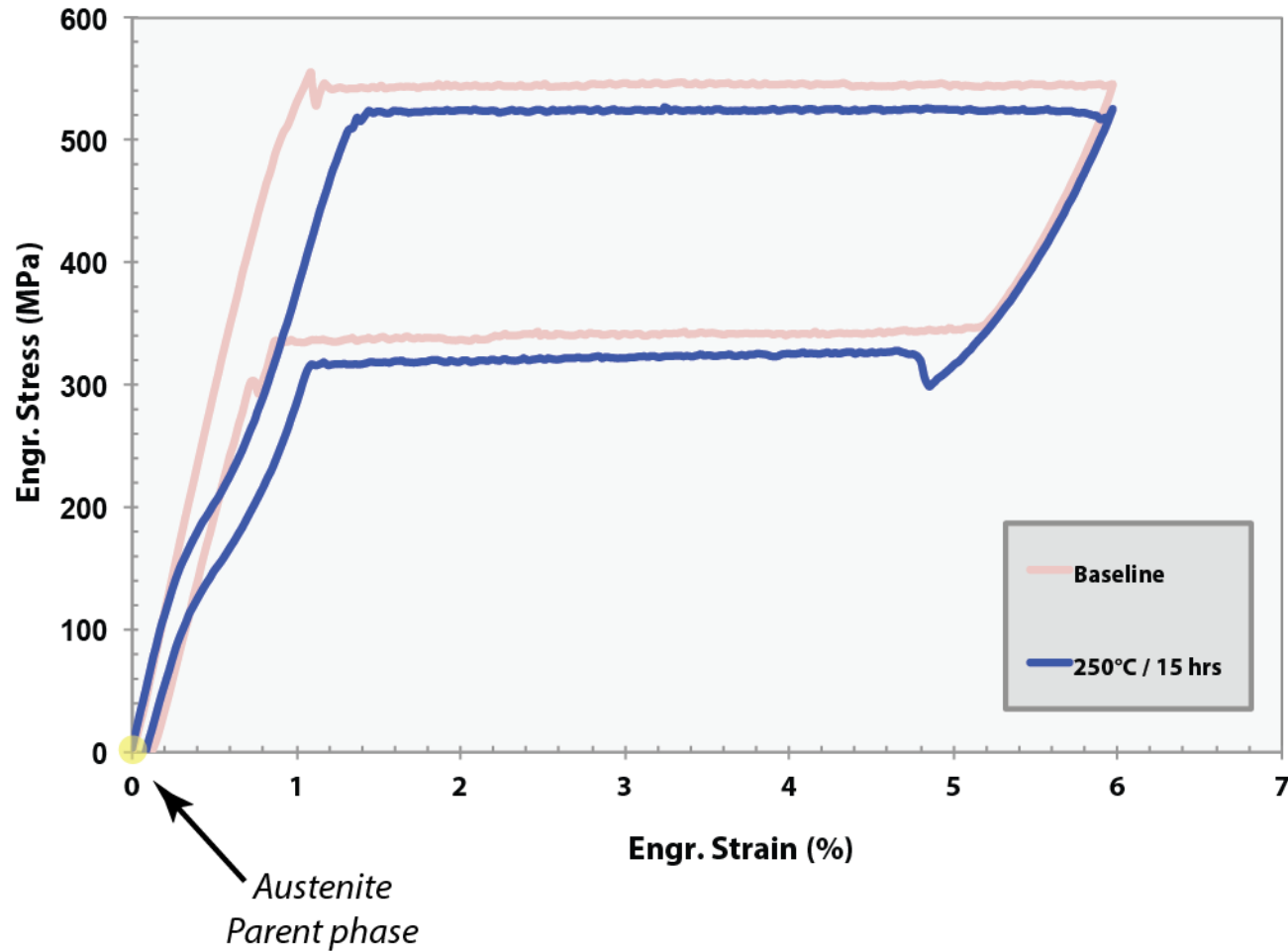
Scenario 1: A-M-A classical superelasticity:



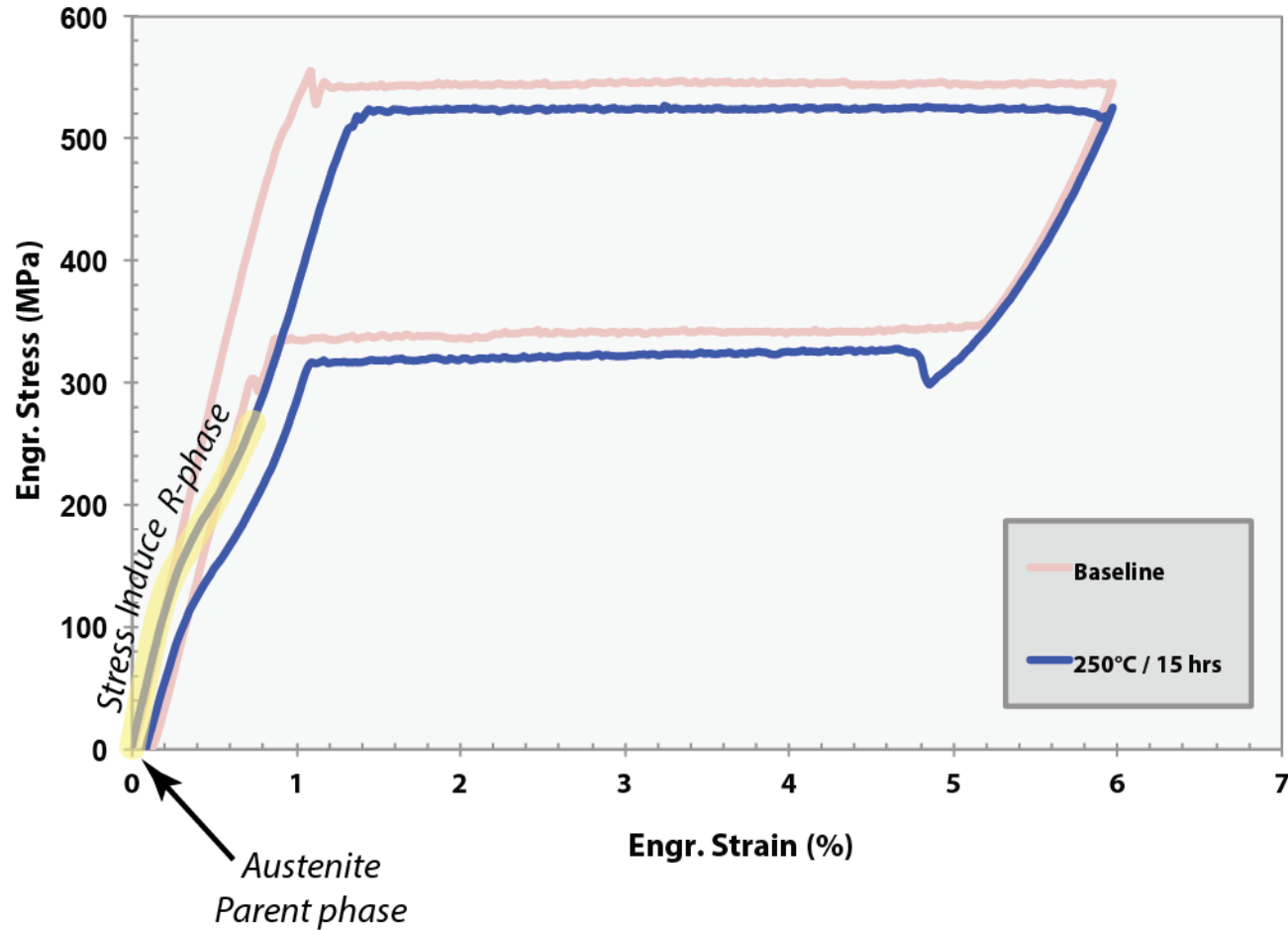
Scenario 1: A-M-A classical superelasticity:



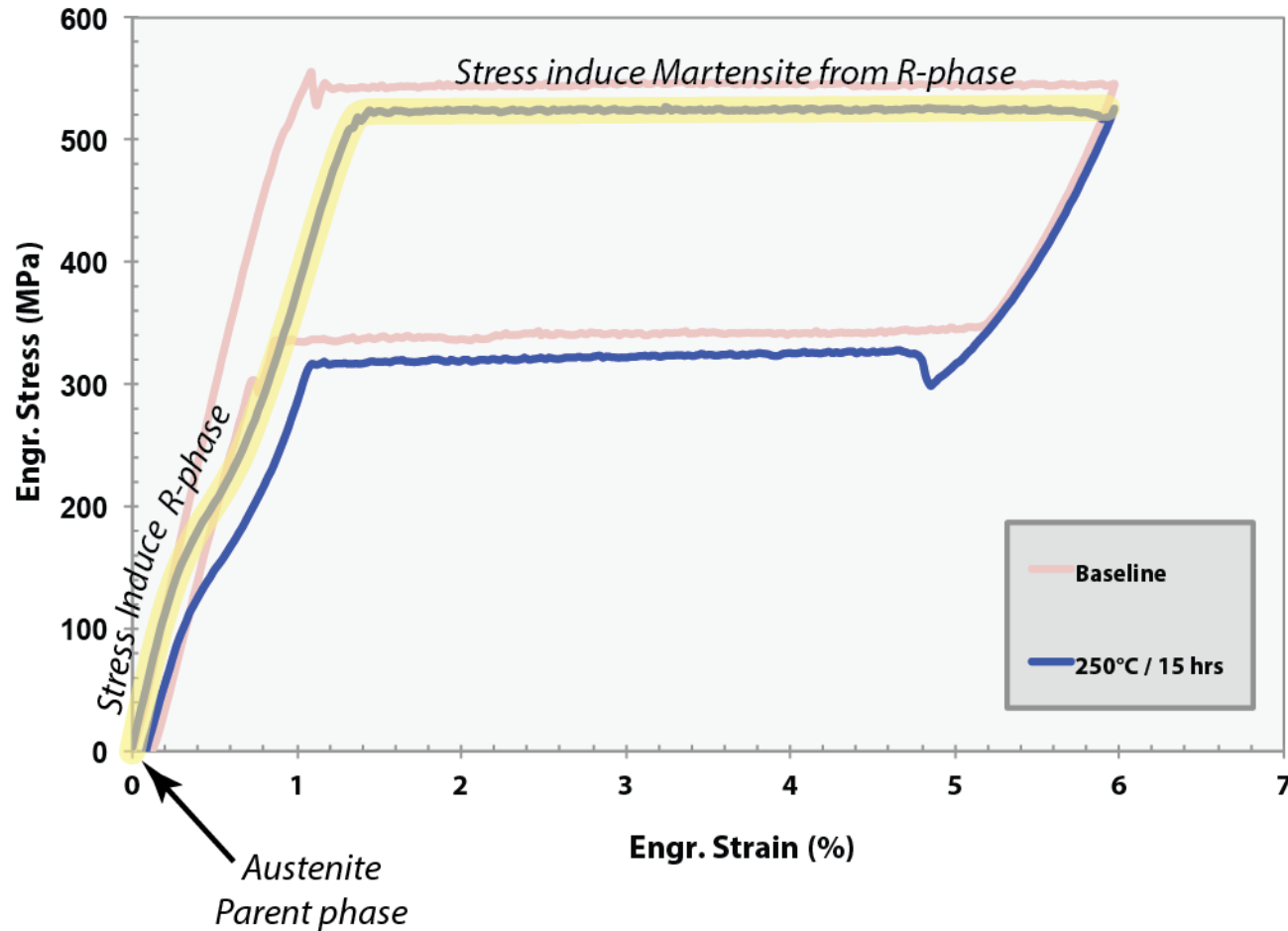
Scenario 2: A-R-M-R-A superelasticity:



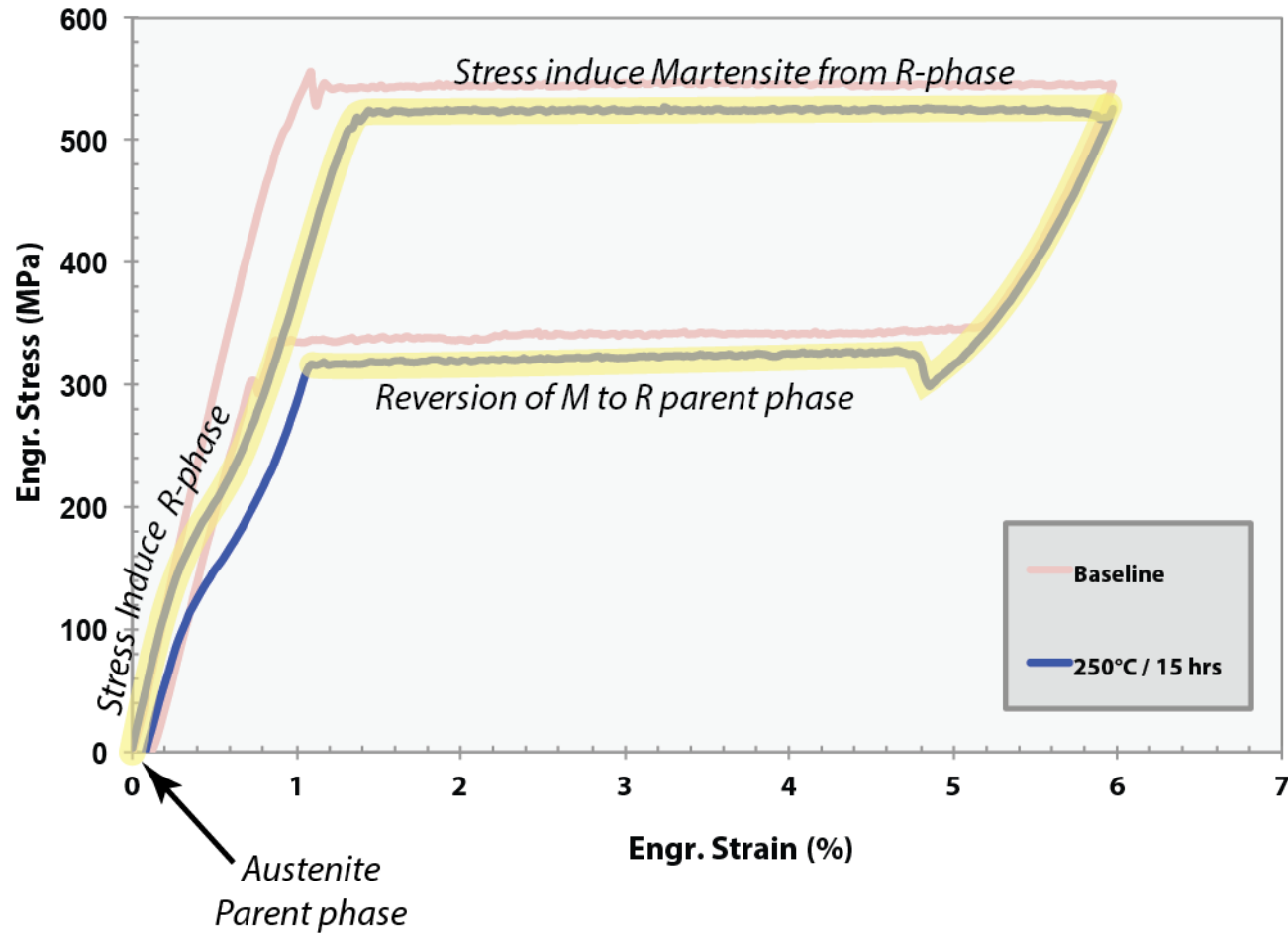
Scenario 2: A-R-M-R-A superelasticity:



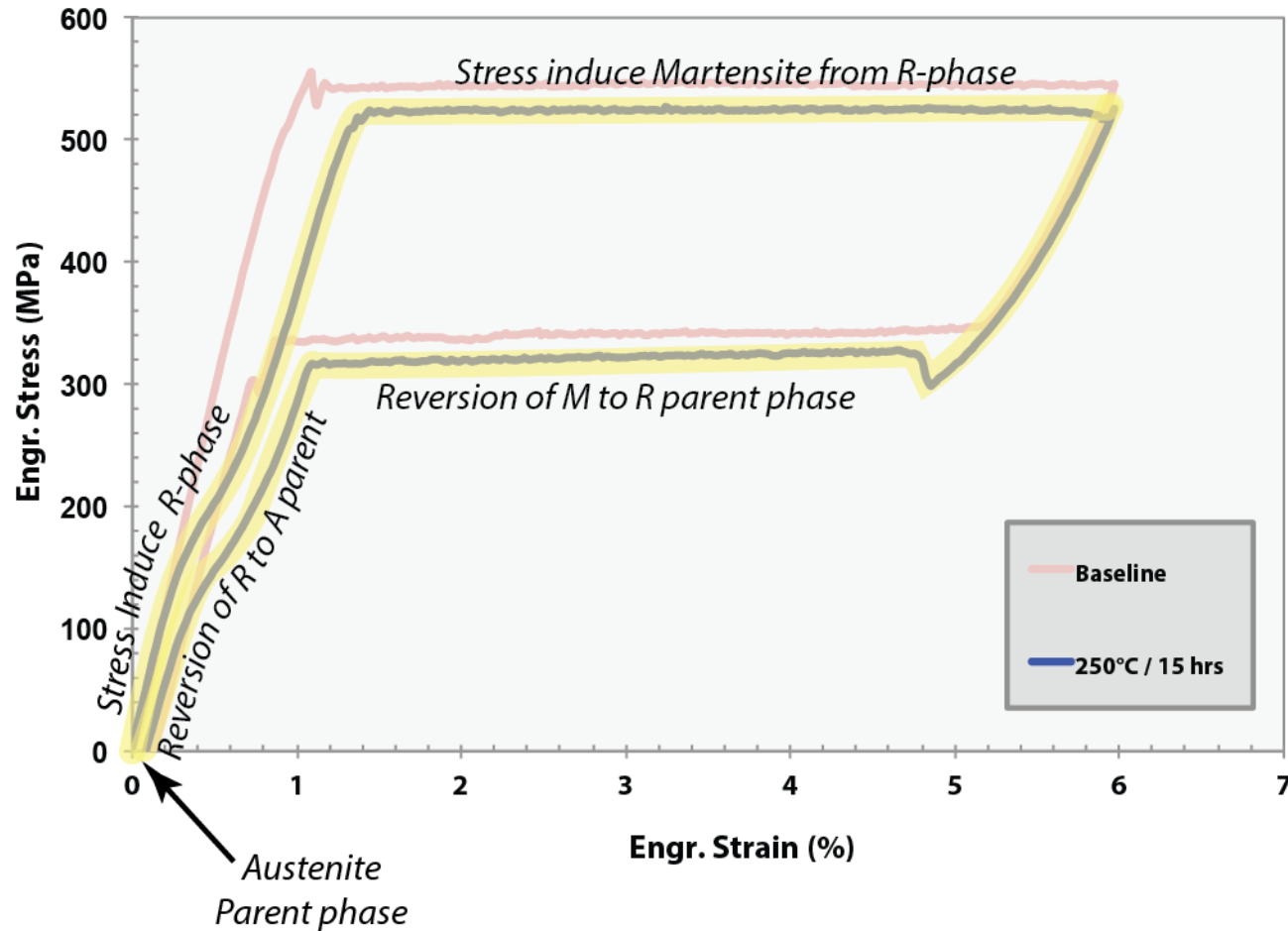
Scenario 2: A-R-M-R-A superelasticity:



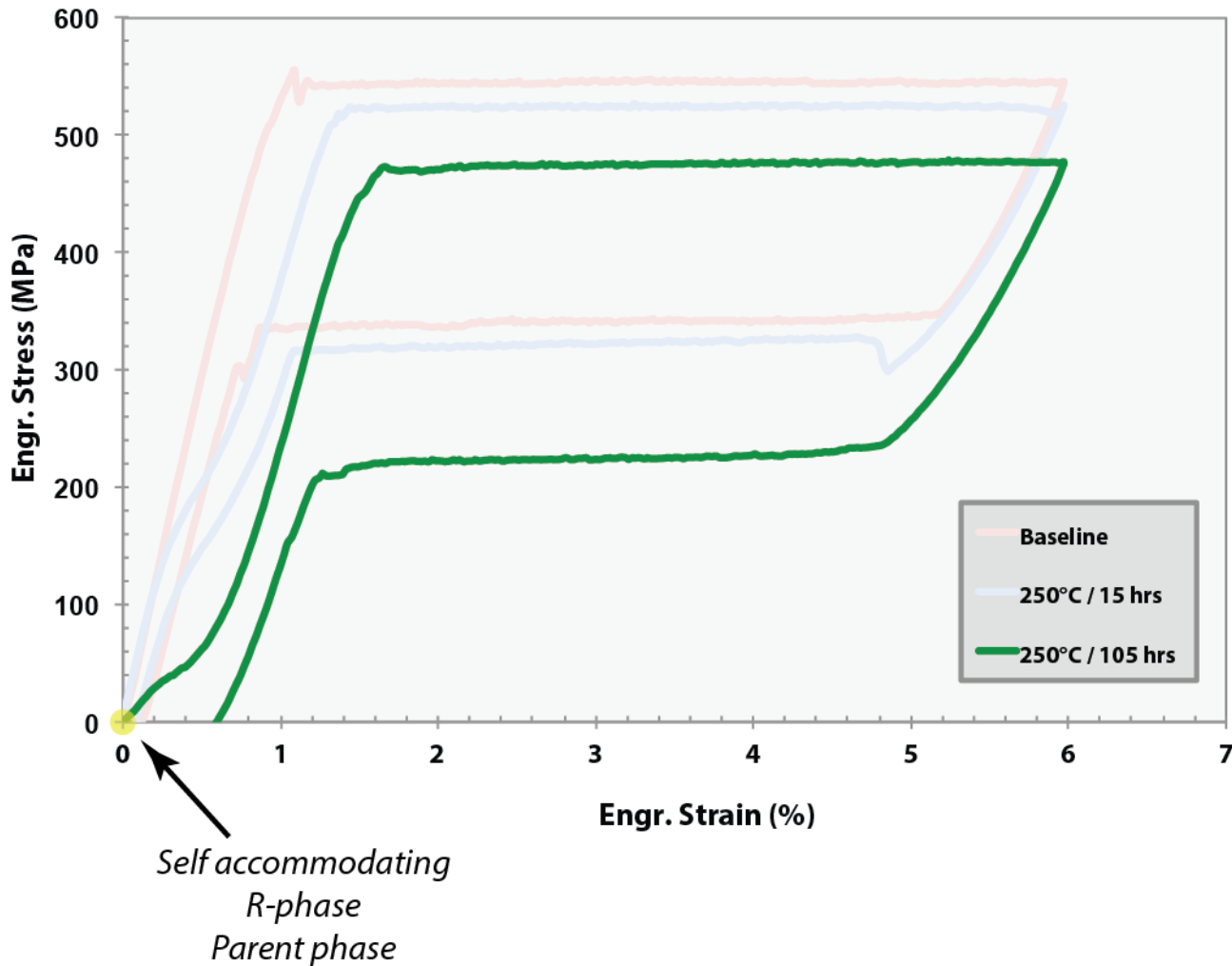
Scenario 2: A-R-M-R-A superelasticity:



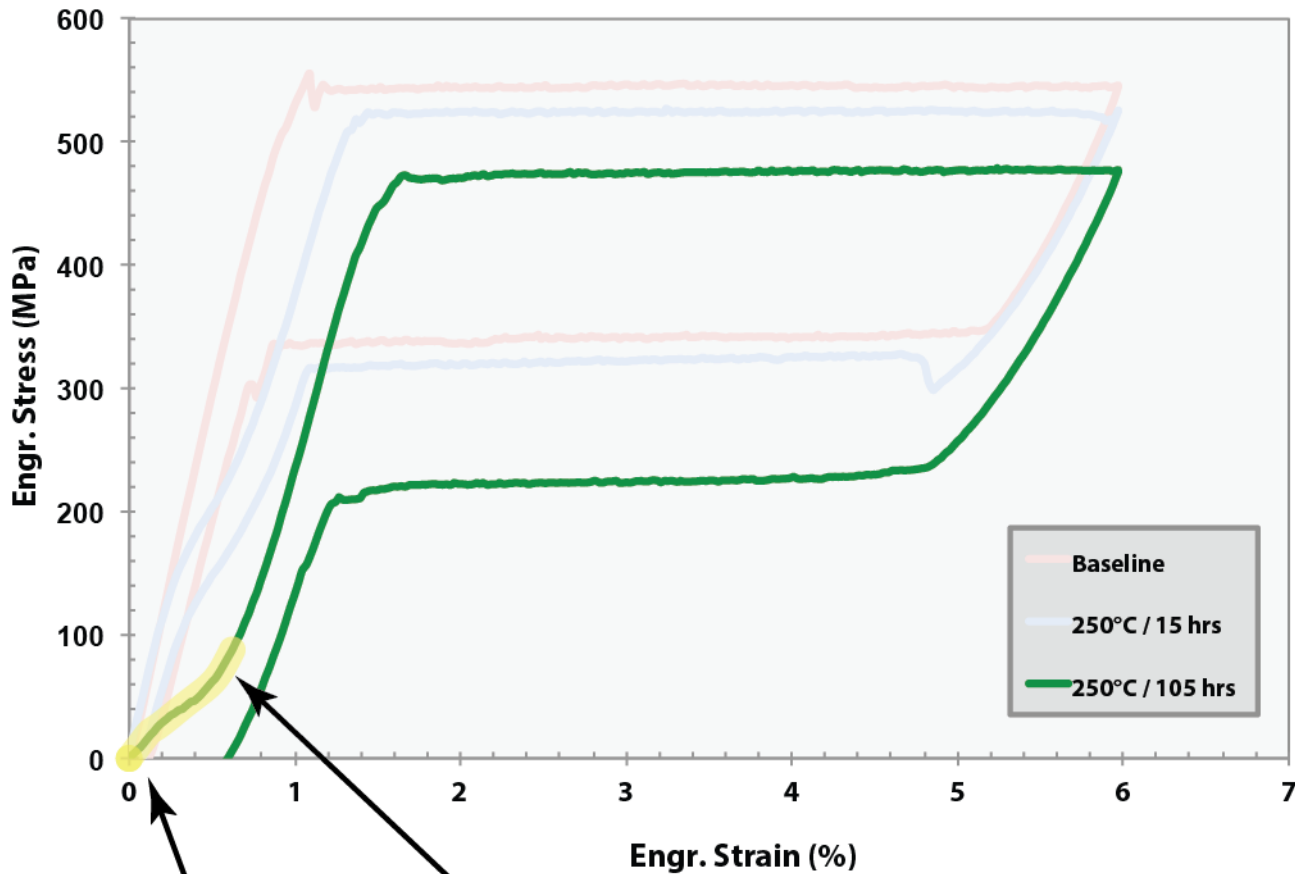
Scenario 2: A-R-M-R-A superelasticity:



Scenario 3: R-M-R superelasticity:



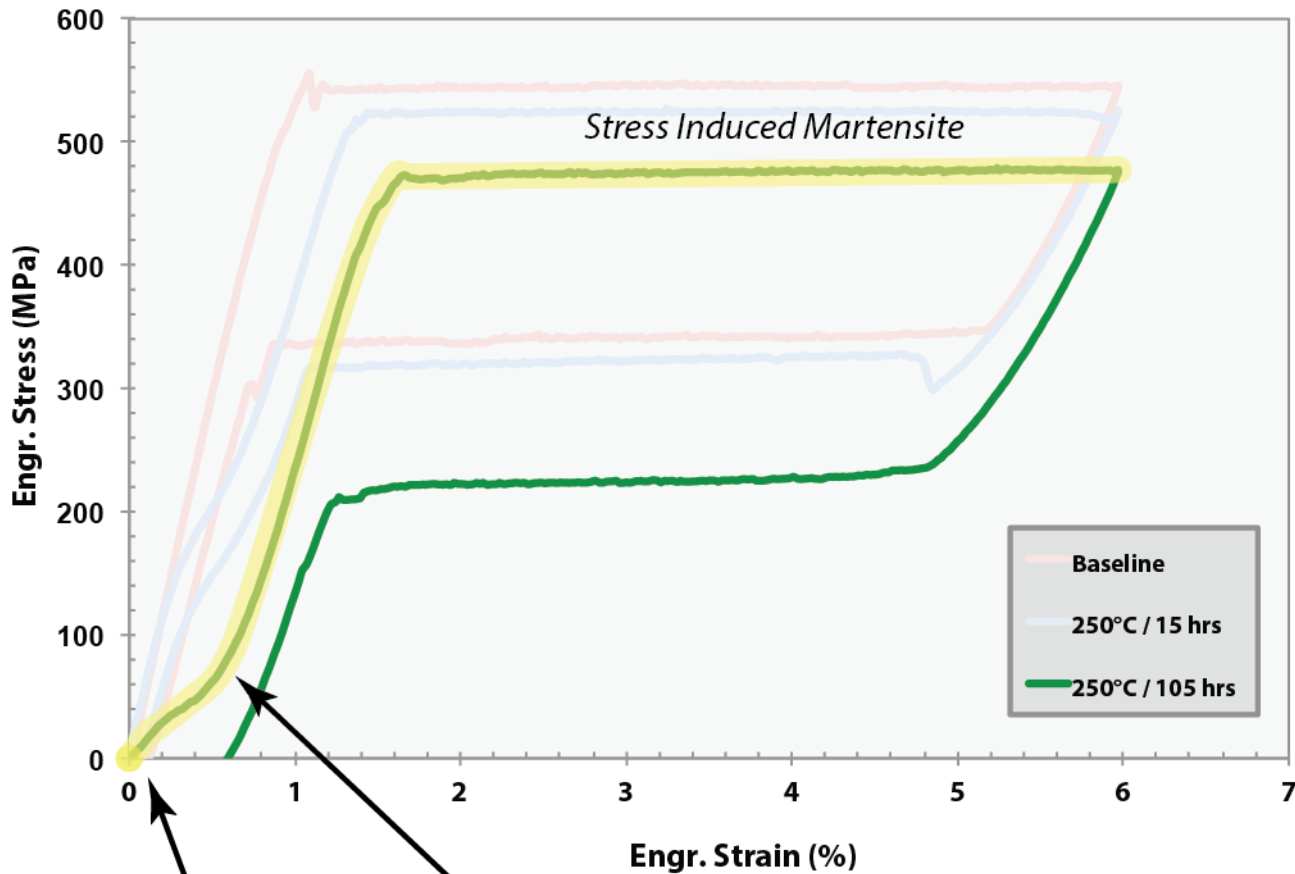
Scenario 3: R-M-R superelasticity:



Self accommodating
R-phase
Parent phase

Optimally
selected
R-phase
variants

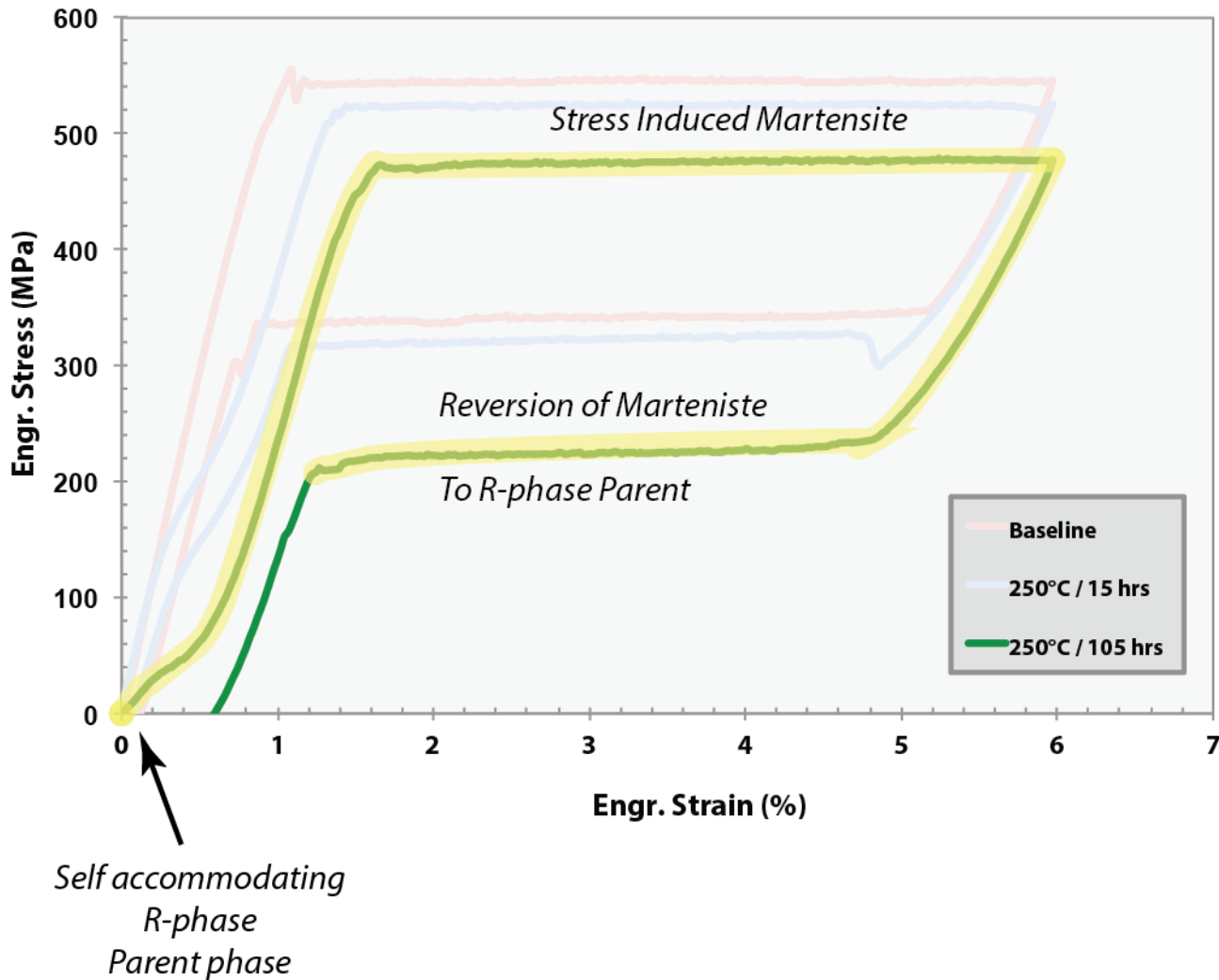
Scenario 3: R-M-R superelasticity:



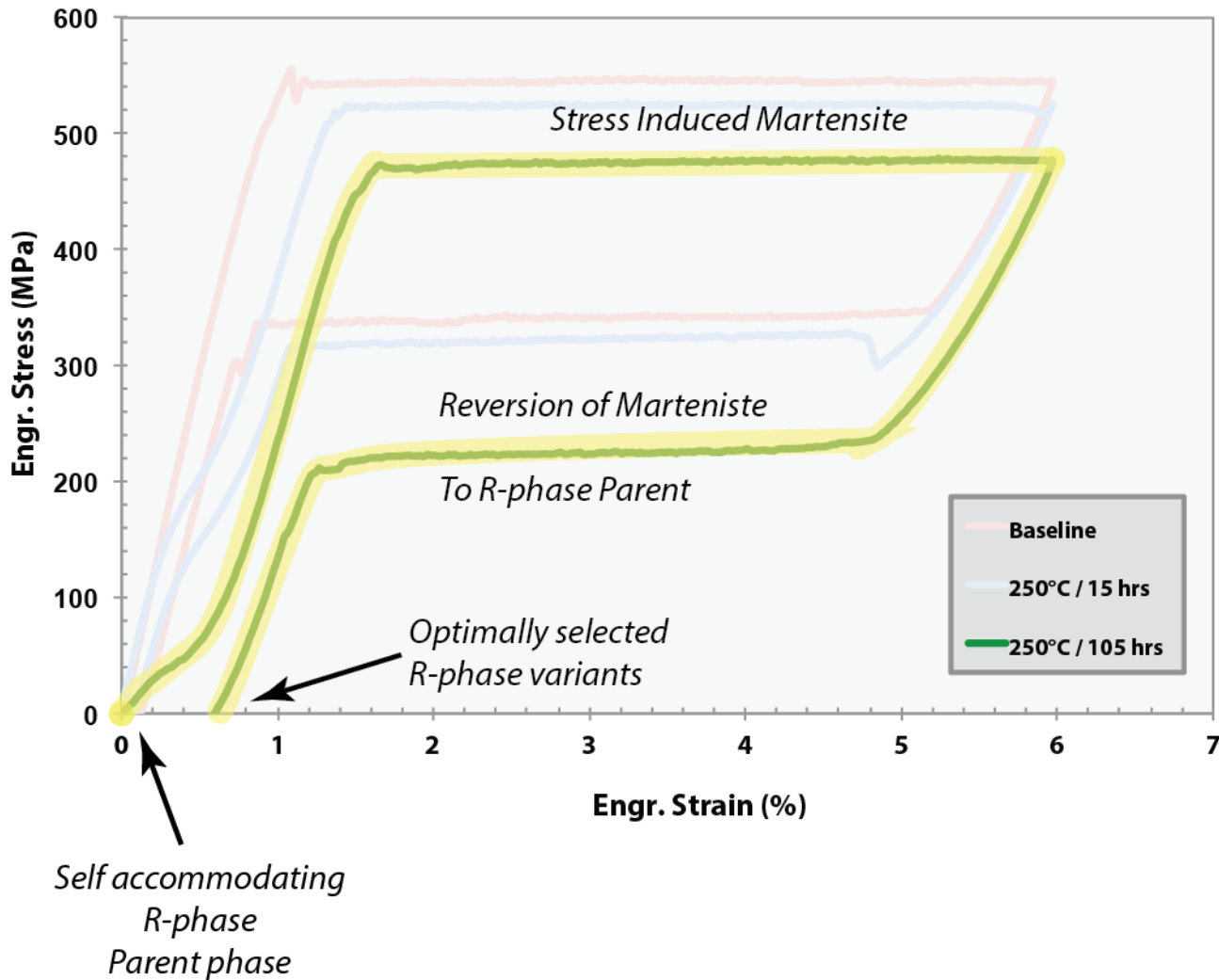
Self accommodating
R-phase
Parent phase

Optimally
selected
R-phase
variants

Scenario 3: R-M-R superelasticity:

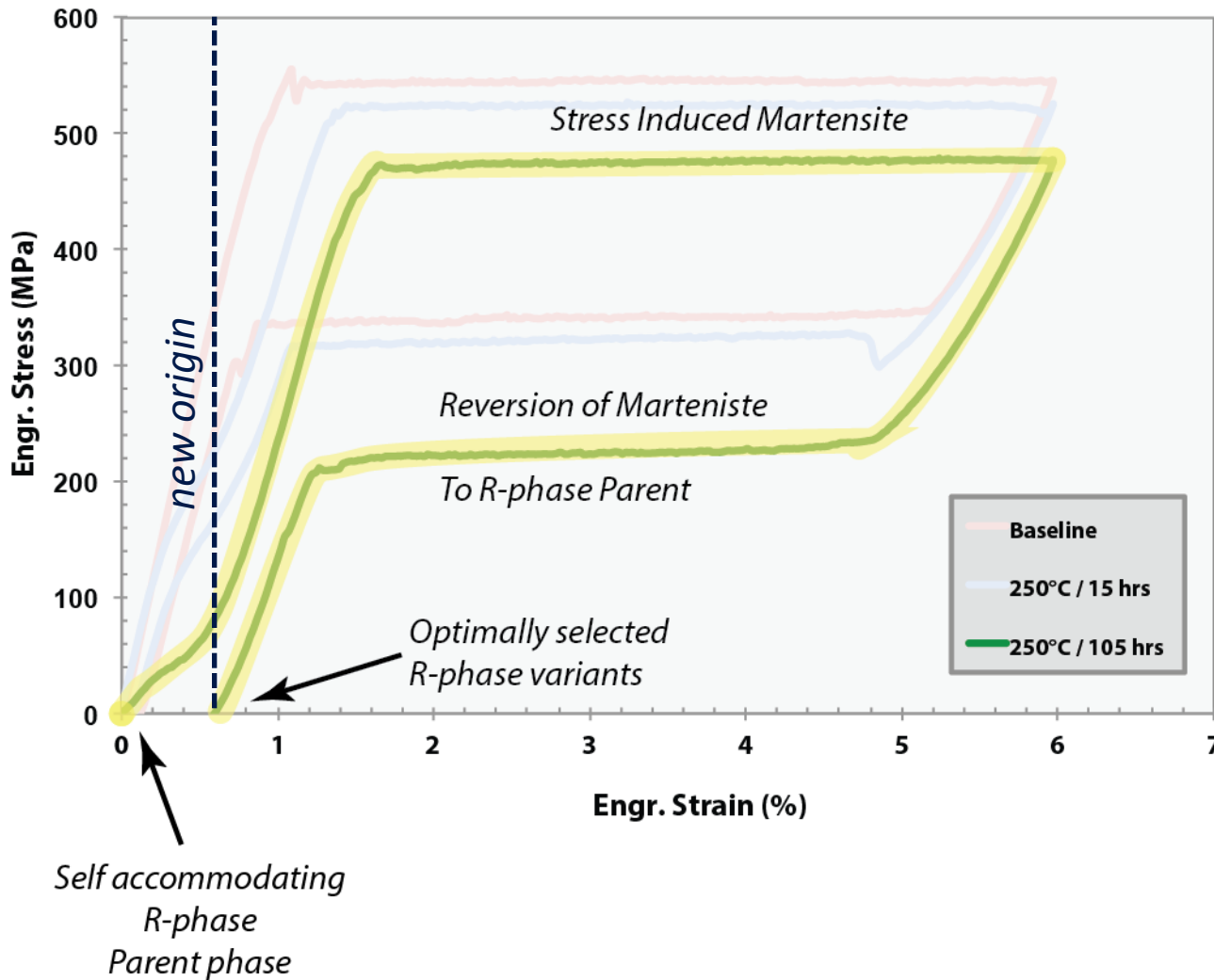


Scenario 3: R-M-R superelasticity:



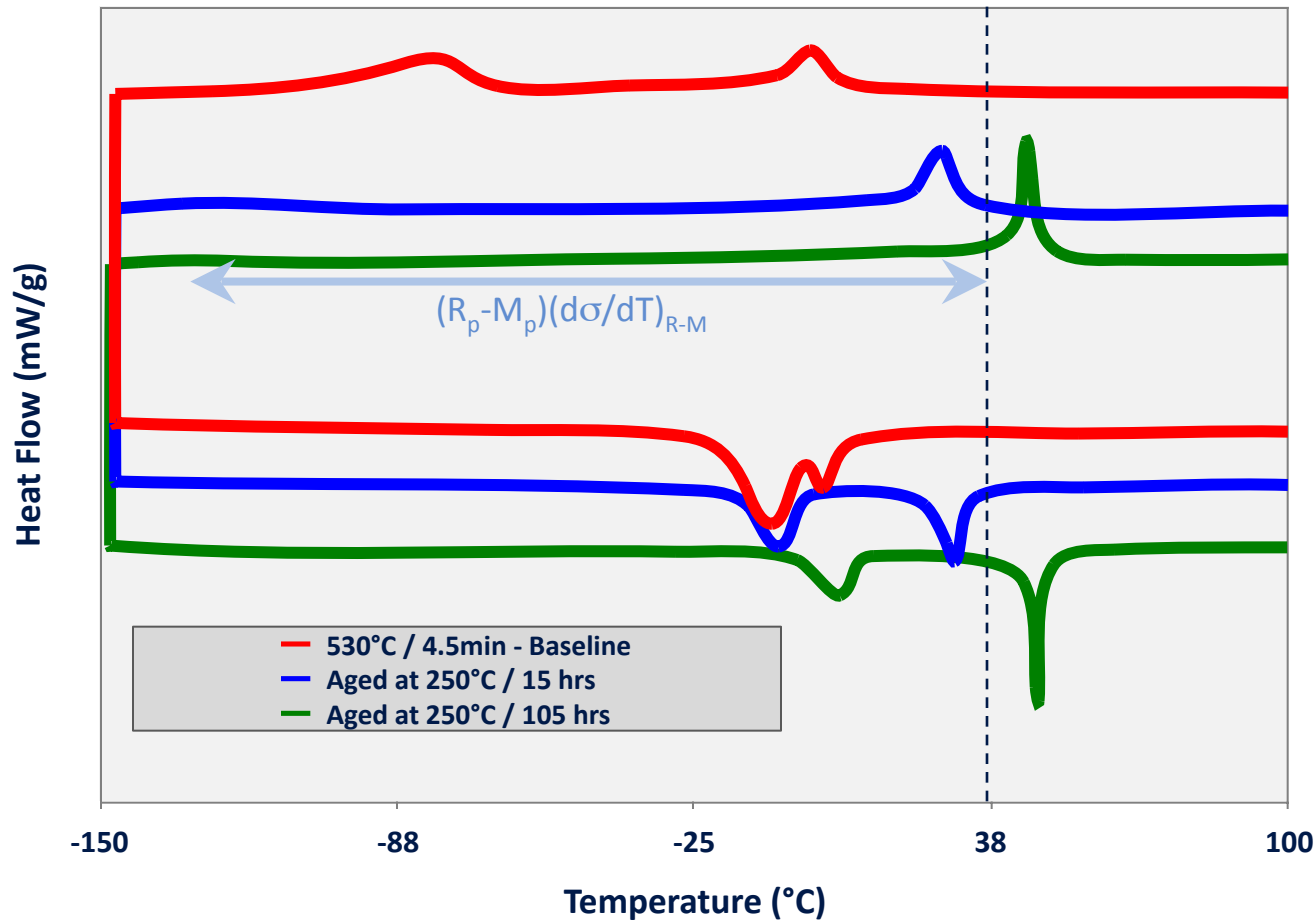
Who cares:

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



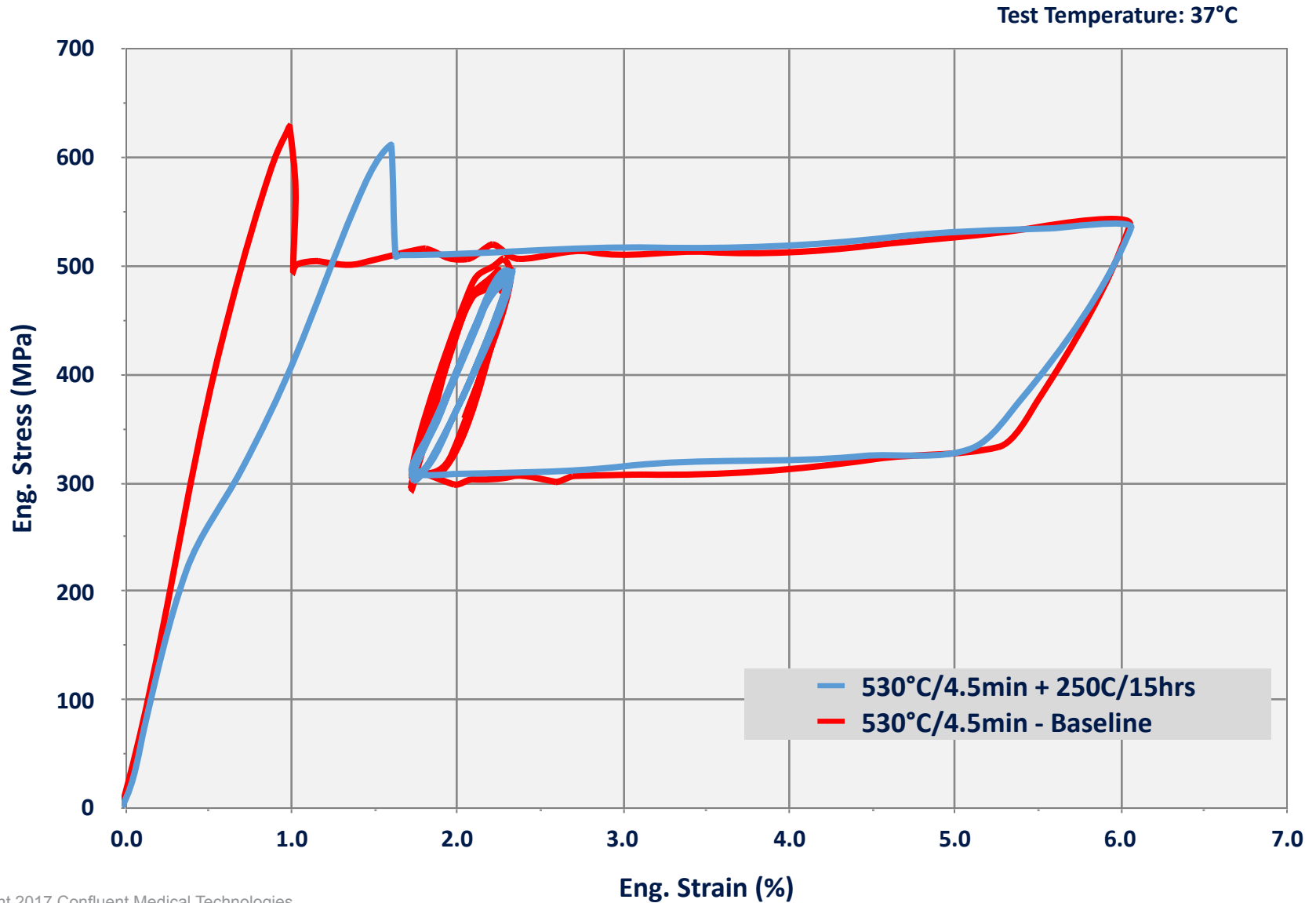
Who cares:

2. $d\sigma/dT$ decreases, extending the superelastic “window”



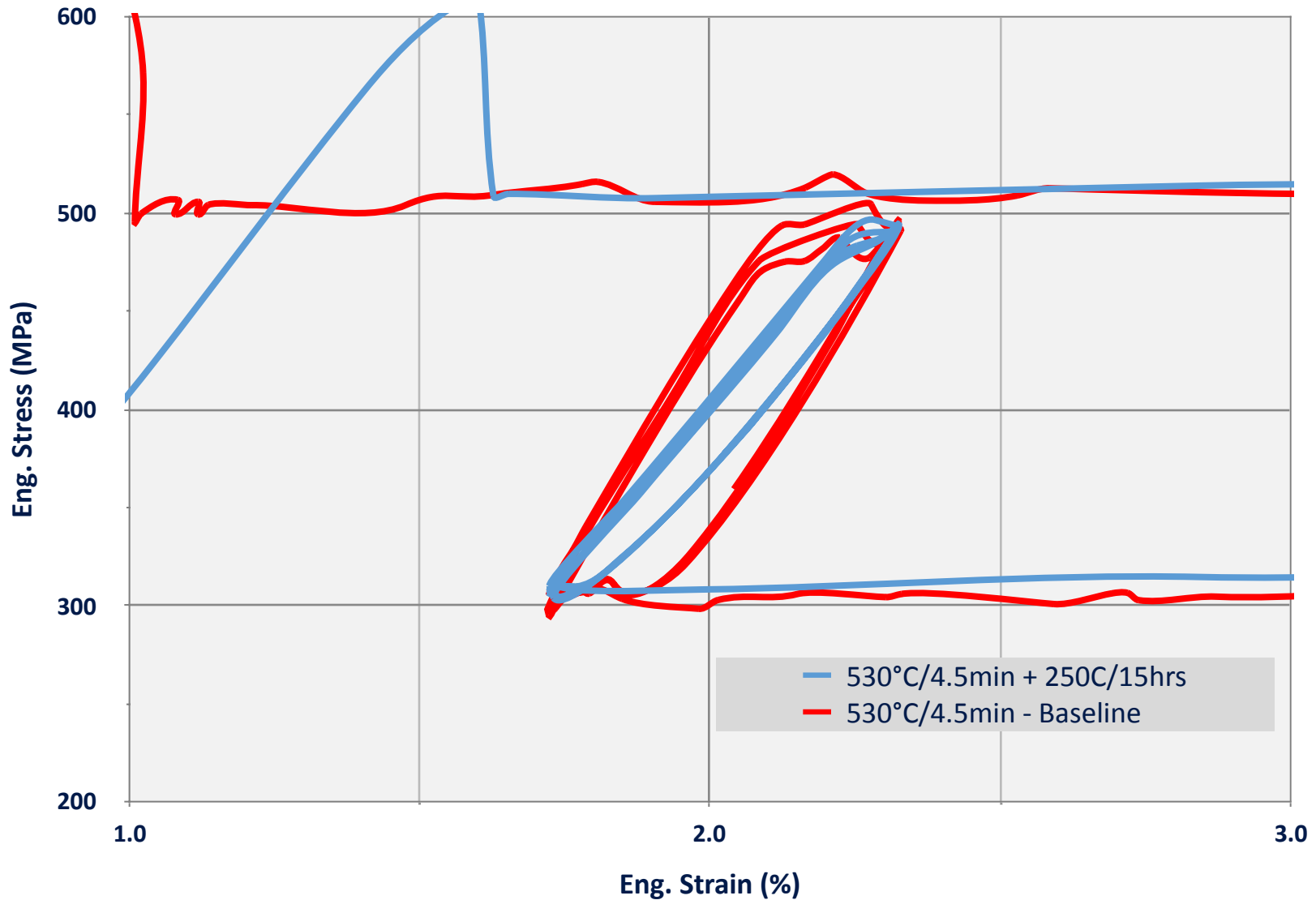
Who cares:

3. Duty cycle is more compliant



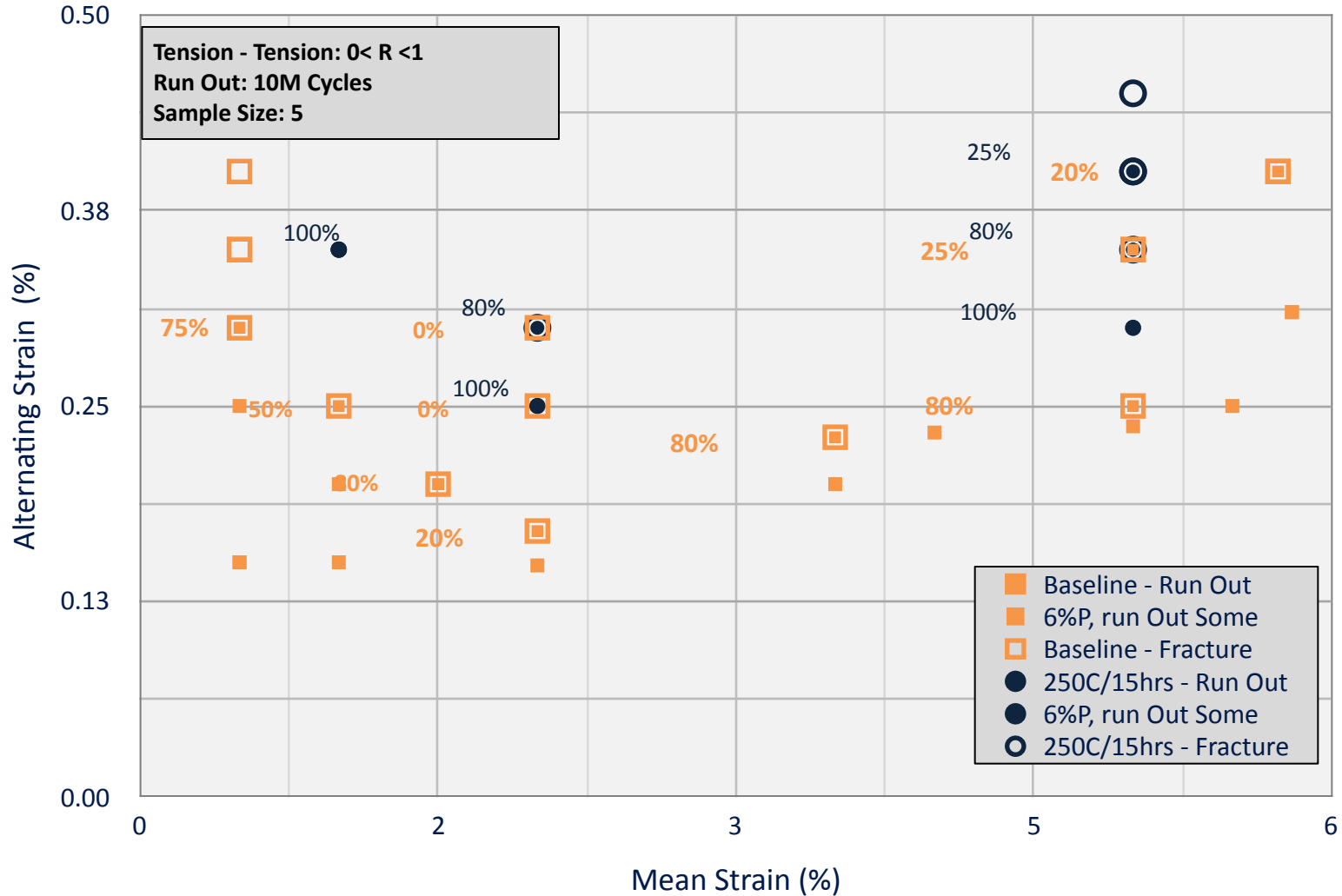
Who cares:

3. Duty cycle is more compliant



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

<http://nitinol.com>

