

The Effect of Reinforcement Substrate Alloy Selection on Mechanical Properties of REBCO Coated Conductor

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Introduction

- REBCO coated conductors (CC) are becoming popular for next generation high field magnets.
- A common design criterion is for 0.4 % strain.
- However, some tapes are already plastic at this strain while others not, depending on substrate choice.
- Hastelloy C276 and 310 stainless steel are two common choices, here tested after simulated REBCO deposition heat treatments.
- The study was started because of variability tape to tape that we observed.

Material Specifications

Table 1: Chemical composition in wt % of 310 stainless steel and Hastelloy C276.

	Ni	Mo	Cr	Fe	W	Mn	Co	C	V	P	S	Si
Hastelloy C276	Balance	15-17	14.5-16.5	4.0-7.0	3-4.5	1	2.5	0.01	0.3	0.04	0.003	0.008
310 Stainless Steel	19-22	-	24-26	Balance	-	2	-	0.25	-	0.045	0.030	1.5

- Both materials are manufactured to resist high temperatures.
- 310 stainless steel is a high nickel austenitic steel alloy immune to strain-induced martensitic transformation.
- Hastelloy is a nickel-base superalloy with significant Mo and W.

Heat Treatment

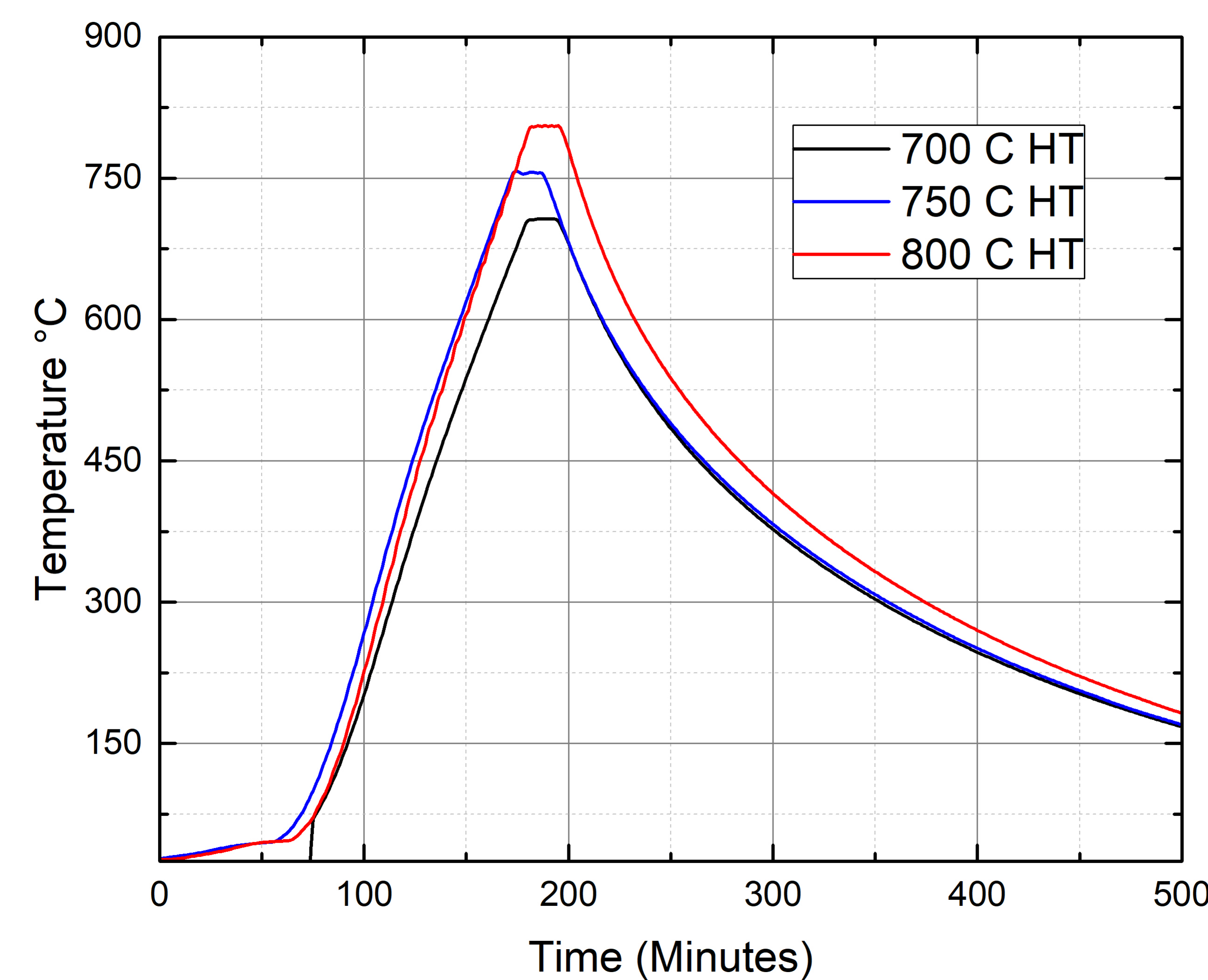


Figure 1: The annealing temperature profiles on bare 310 stainless steel and Hastelloy C276 substrates.

- The HT profile was aimed to simulate a REBCO deposition step.
- We wished to understand whether any annealing would occur to these cold rolled substrates.
- Heat treatments at 700, 750 and 800 C were done on separate samples.

Tensile Testing Fixture

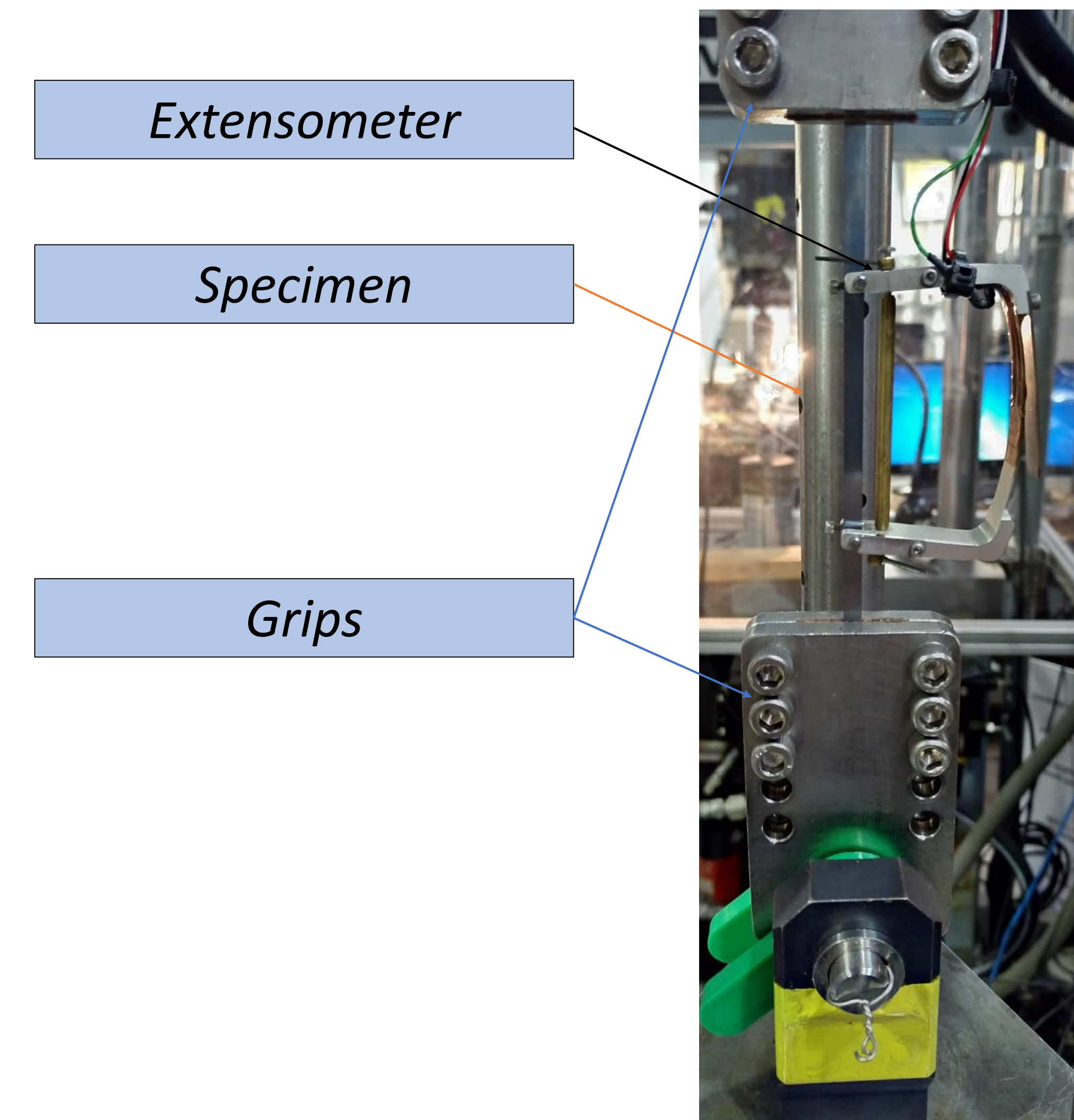


Figure 2: Tensile testing fixture setup

- Figure 2 shows the tensile testing setup.
- Strain was measured with a two inch extensometer.
- Samples were strained at a rate of $1.64 \times 10^4 \text{ } \epsilon/\text{sec}$.
- All samples were tested at 293 K.
- 310 stainless steel samples were 100 μm thick.
- Hastelloy samples were 50 and 30 μm thick.

Results

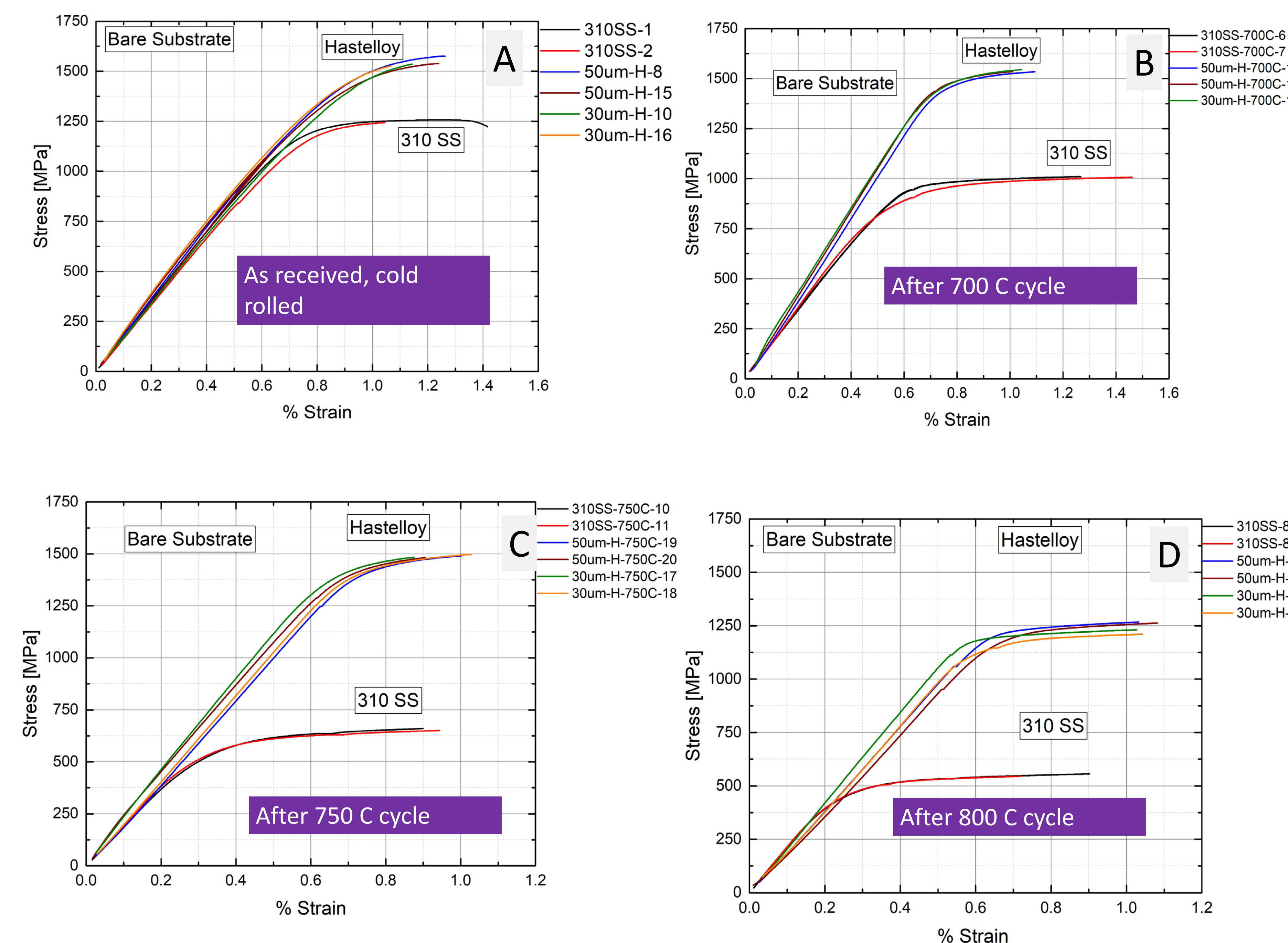


Figure 3(A-D): Stress-strain relationship of 310 stainless steel and Hastelloy C276 in the as received, 700, 750, and 800 C condition tested at 293 K

- From the 23 samples measured, we saw that 310 stainless steel was heavily influence by the heat treatment. We had earlier noticed variability of mechanical properties in coated conductors deposited on 310 SS.
- By contrast, Hastelloy C276 was only weakly affected by our heat treatment.

Discussion

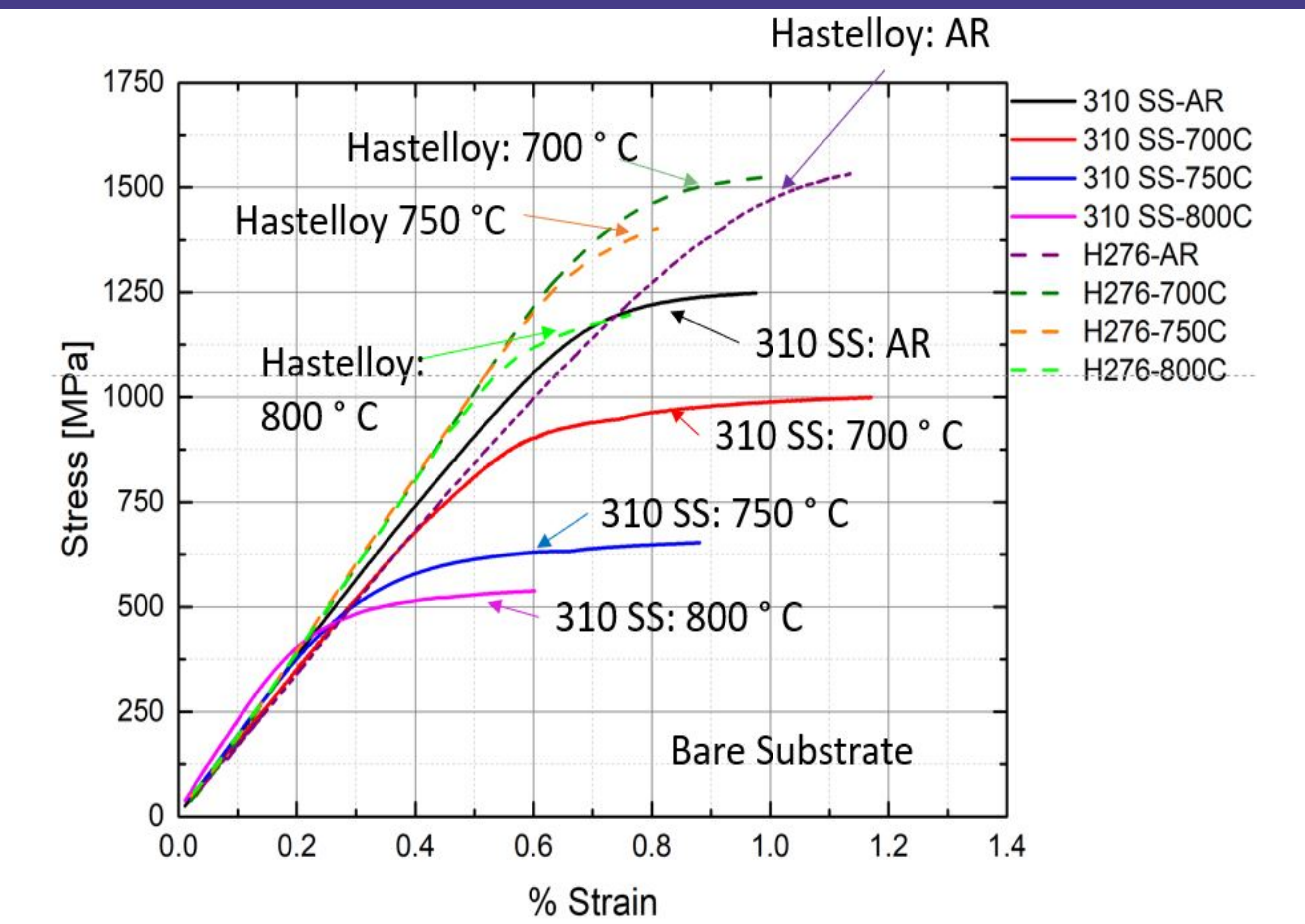


Figure 4: Average stress-strain trend of as-received and heat treated 310 stainless steel and Hastelloy C276 bare substrates tested at 293 K.

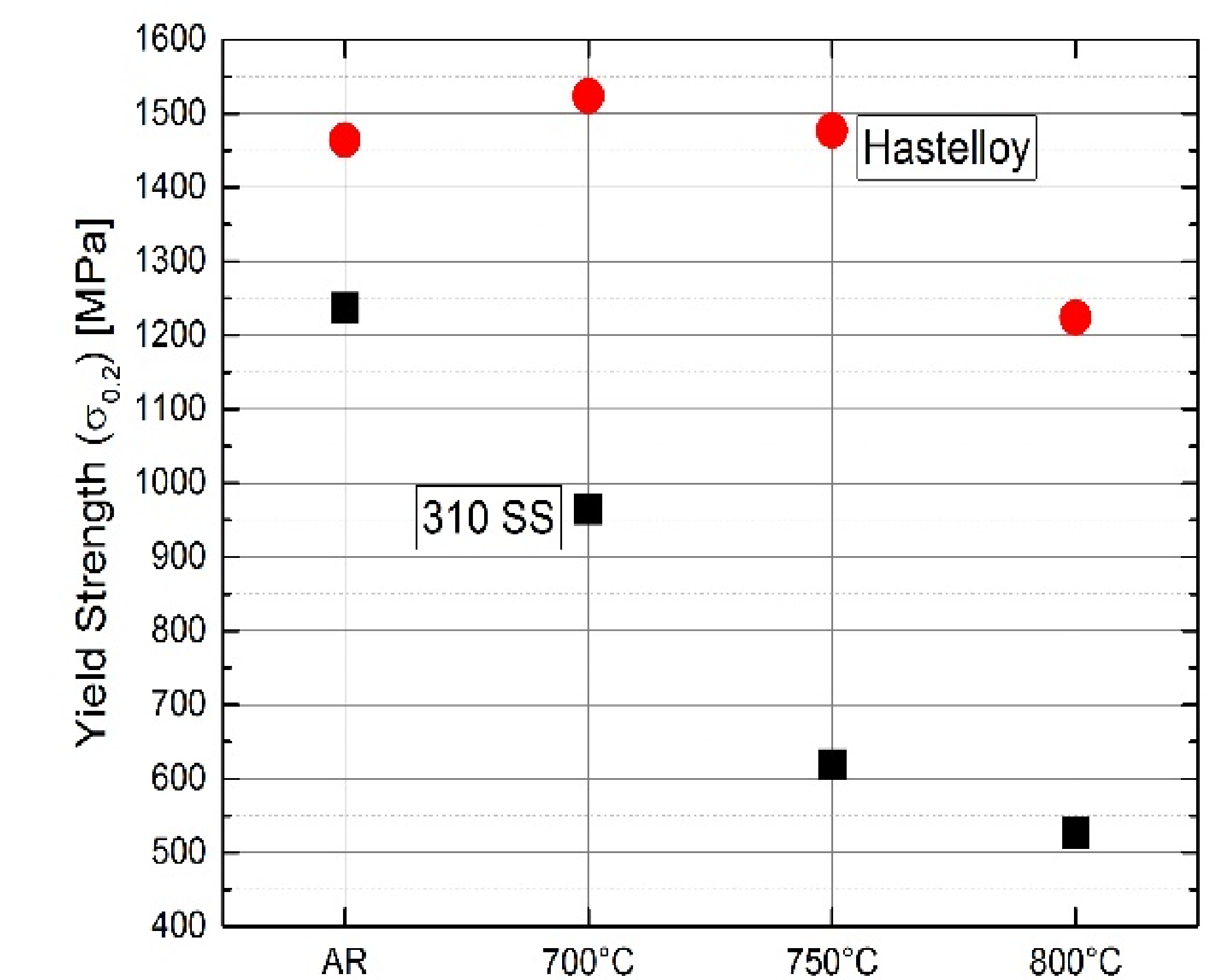


Figure 5: Yield Strength vs heat treatment on 310 stainless steel (black square) and Hastelloy C276 (red circle).

- Hastelloy C276 showed an enhanced yield strength after the 700 and 750 C heat treatments but a slight weakening after the 800 C heat treatment
- 310 stainless steel showed continuous weakening compared to the as-received condition.

Conclusion

- It does appear that small variations in REBCO processing temperature may exert significant effect on the strength of conductor using cold rolled 310 SS substrates.
- 310 stainless steel is also significantly weaker than Hastelloy C276, even if it is cheaper.
- Hastelloy C276 was much more resistant to heat treatment and stronger, making Hastelloy a better substrate for high field magnets.