Plastic Flow Instability in Austenitic Stainless Steels at a Wide Range of Temperatures: From Macroscopic Tests to Microstructural Analysis

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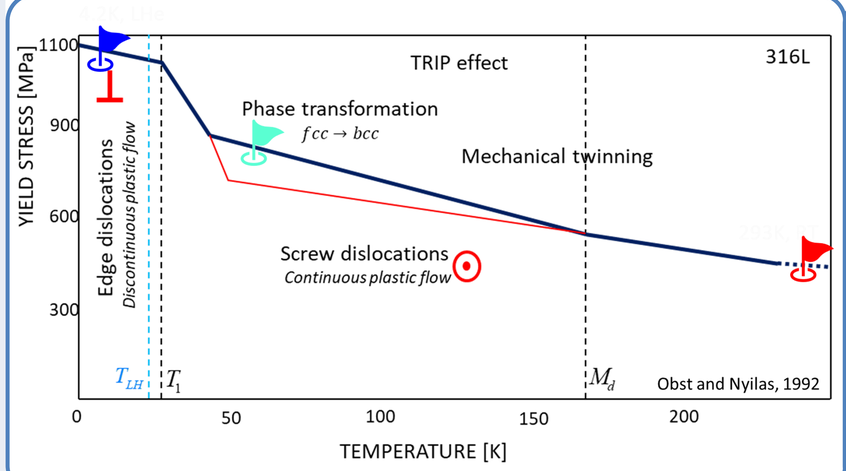
ABSTRACT: Deformation-induced phase transformation stabilizes the macroscopic shear band propagation in the metastable austenitic stainless steels (304, 316L). At room temperature, this strain localization arises only in the metastable 304 ASS at the final stage of the tensile test. The front, where the strain drop reaches almost 10%, propagates continuously through the specimen. Temperature decrease to 4K diametrically changes the nature of the shear band. Its propagation is sequential and discontinuous and starts at the beginning of a tensile test. The formation of an individual shear band induces a rapid drop of stresses followed by their gradual growth in the elastic and plastic range, which proceeds in an adjacent area belonging to the next band. The phase transformation is concentrated at the boundary of the shear band, where two different deformation fields are in contact.

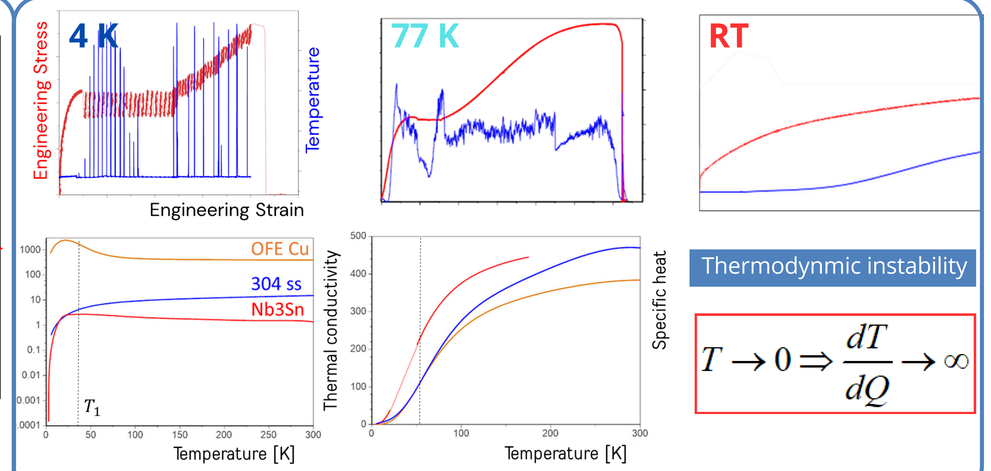
PLASTIC FLOW INSTABILITY IN ASS:

- The phase transformation is triggered in the metastable ASS below the **Md** temperature, which depends on the chemical composition.
- In turn, the discontinuous plastic flow instability occurs below the **T1** temperature due to a change in the deformation mechanism in which edge dislocations dominate instead of screw ones.
- In the proximity of absolute zero, an arbitrarily small energy dissipation in the lattice (for instance, induced by localized plastic deformation) produces a significant increase in temperature in the form of δ-Dirac function— it is so-called **thermodynamic instability.**
- The front propagation in ASS at wide range of temperature is attributed to the accumulation of strain rate within a narrow band. Although it exhibits similarities to necking caused by plastic instability, the enhanced strain hardening promotes the stable propagation of the localized strain band, thereby increasing the ductility of the metastable specimen **(TRIP effect).**

Behaviour of 316L as a function of temperature



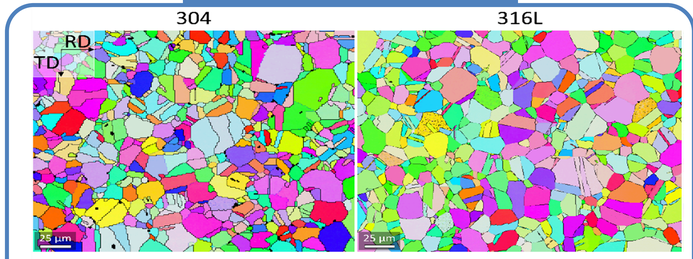
Thermo-mechanical responce



Thermodynmic instability

$$T \rightarrow 0 \Rightarrow \frac{dT}{dQ} \rightarrow \infty$$

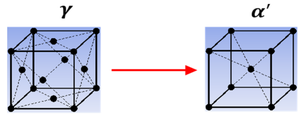
Microstructure 304 vs. 316L



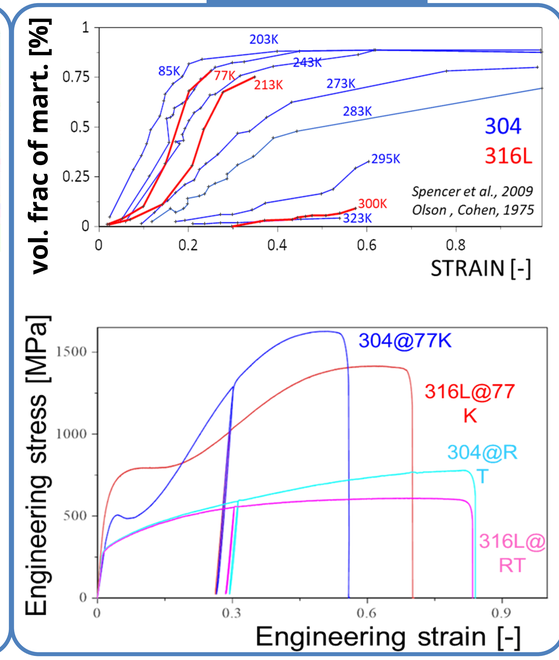
	Chemical composition %								
	C	Si	Mn	Ni	P	S	Cr	Mo	N
304	0.070	0.80	2.00	10	0.045	0.030	18	-	-
316L	0.030	1.00	2.00	11.50	0.045	0.015	18.20	2.00	-

Stacking fault energy

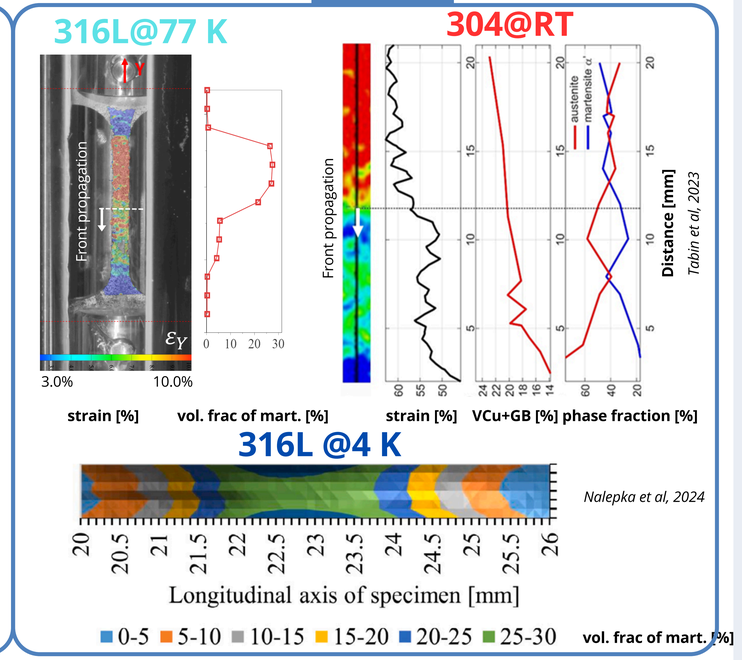
304	<18 mJ/m^2
316L	>20 mJ/m^2



DIMT 304 vs. 316L



TRIP effect



CONCLUSIONS:

- Tension-induced microstructure gradient in ASS triggers a propagation of strain band at a wide range of temperatures.
- Cu and GB oriented grains and martensite content determine plastic instability.
- A similar pattern of plastic instability is observed in 304 under tension at 4K, 77K, and RT.
- DIC-enhanced experimental platform with a multi-detector array effectively monitors strain field evolution in cryogenic conditions.

FUTURE WORK:

- Develop an experimental setup for monitoring the evolution of strain fields in materials at 4K.
- Validate the mechanical properties of additively manufactured 316L stainless steel across a wide range of temperatures (4K, 77K, and RT).

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