DEPARTMENT of APPLIED MECHANICS

Acoustic Emission and Infrared Thermography Study of Low Strain Tensile Behaviour of AISI 304L Stainless Steel

Katedra aplikovanej mechaniky - UNIZA

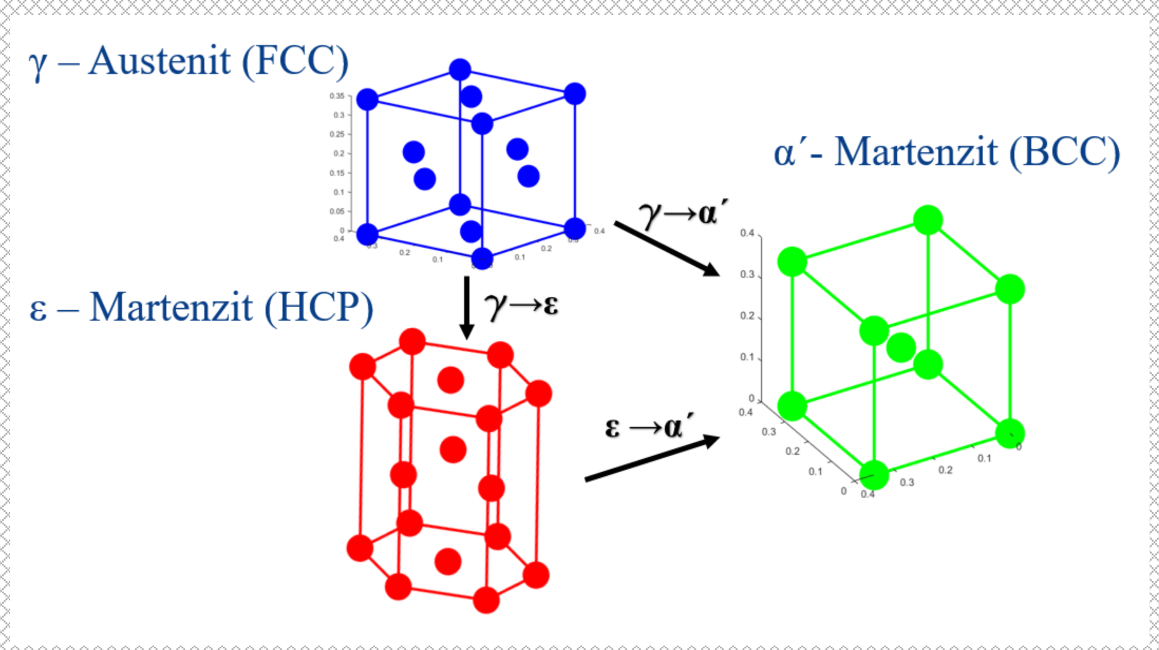
Theoretical basis

Deformation/transformation mechanisms are driven by:

- **Stacking Fault Energy of material (SFE);**
- **External driving force/deformation, temperature (magnitude, rate, directionality,...) .**

Material composition of investigated AISI 304L Stainless Steel (SS) in weight %:

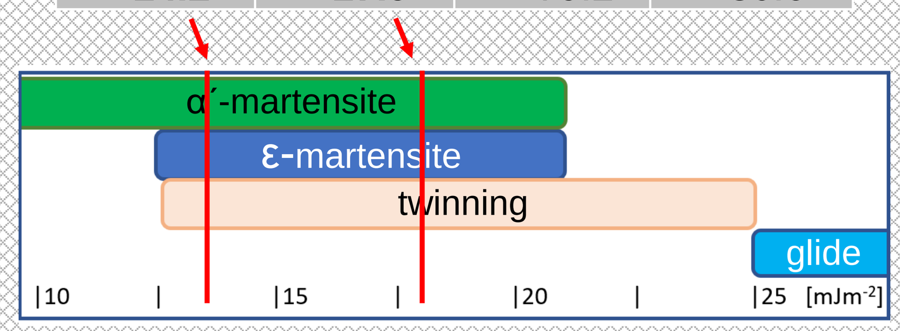
C	Si	Mn	P	S	Ni	Cr	Co	N
0.024	0.41	1.49	0.034	0.003	8.03	18.05	0.245	0.069



Crystal structures in AISI 304L stainless steel. Arrows indicate the transformation mechanisms.

SFE computed according to Schramm&Reed (SFE_{S-R}) and Brofmann&Ansell (SFE_{B-A}) lies in the coexistence range of α´-martensite, ε-martensite and twinning.

SFE_{S-R} [mJm^{-2}]	SFE_{B-A} [mJm^{-2}]	M_s [°C]	M_{d30} [°C]
14.2	**17.9**	-79.2	30.6



Occurrence of mechanisms with respect to SFE at low strains in austenitic stainless steels according to Galindo-Nava [1].

Published data on tensile tests of AISI 304:

Strain rate

- $\dot{\varepsilon} = 5x10^{-4}s^{-1} \rightarrow Q_{generated} = Q_{dissipated}$ [2]
- Increasing strain rate → heating of specimen, suppression of transformation. [3]

Mechanisms

- Lowest strains: Shockley partial dislocations, formation of stacking faults (SF);
- Low and moderate strains: Bundling and overlapping of SFs, creation of shear bands, ε-martensite transformation;
- Moderate and high strains: ε→α´ transition, twinning, γ→α´ transition.

*Published results are inconsistent in terms of mechanism vs strain – high variation with SFE and external driving.

In the presented work, Acoustic Emission (AE) and InfraRed Thermography (IRT) have been used as the suitable NDE techniques for in-situ investigation of mechanisms during tensile loading of AISI 304L SS.

Experiment setup

Mechanical

- Set of 8 tensile tests at room temperature
- Two strain rates $\dot{\varepsilon} = 7x10^{-4}s^{-1}$, $\dot{\varepsilon} = 1.4x10^{-4}s^{-1}$
- Dog bone specimens,10 mm x 3 mm – 70 mm
- Loading device: Testometric M500-50CT

Acoustic emission

- System: Vallen AMSY-6
- Sensors: wideband Vallen VS45, VS900
- Guard sensor technique - noise events separated

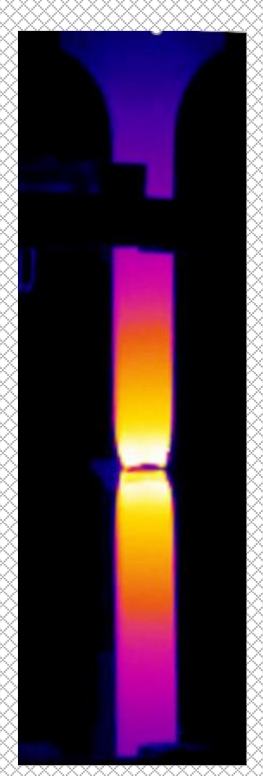
Infrared thermography

- High speed infrared camera Flir SC7500 (InSb, MWIR)

Results I.

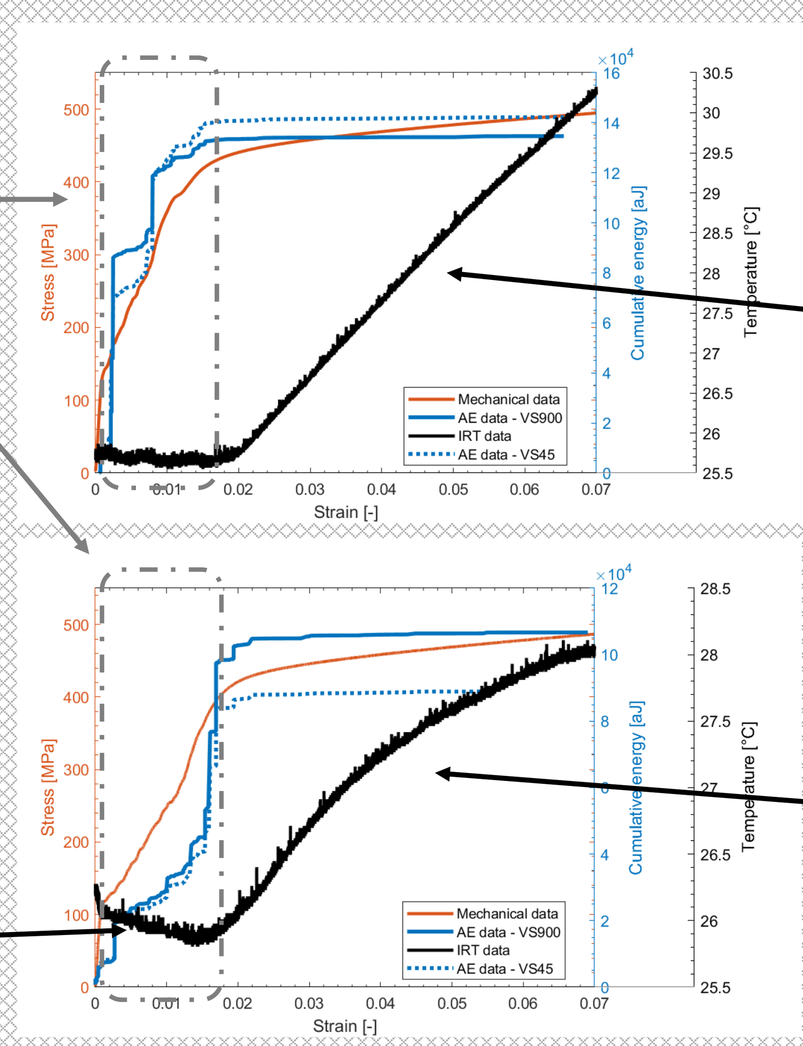
Deformation up to 7%

Stress-strain curves are plotted with cumulative AE energy and maximum temperature.



Dashed line box: area of cumulative AE energy increase coincide well with the area of non-linear stress-strain character and the area of slow temperature change.

Effect of temperature drop below the yield point reported by Kozlowska [4].



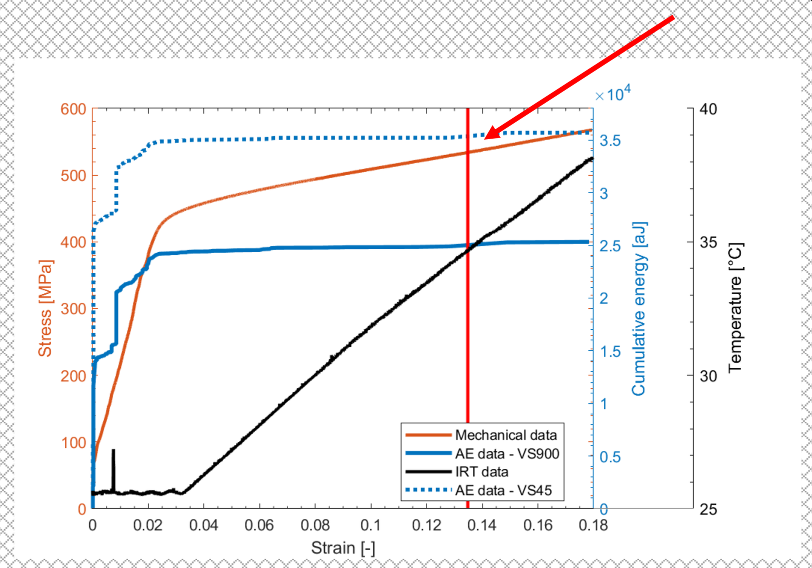
$\dot{\varepsilon} = 7x10^{-4}s^{-1}$
Nearly linear maximum temperature Increase.

$\dot{\varepsilon} = 1.4x10^{-4}s^{-1}$
Concave maximum temperature increase.

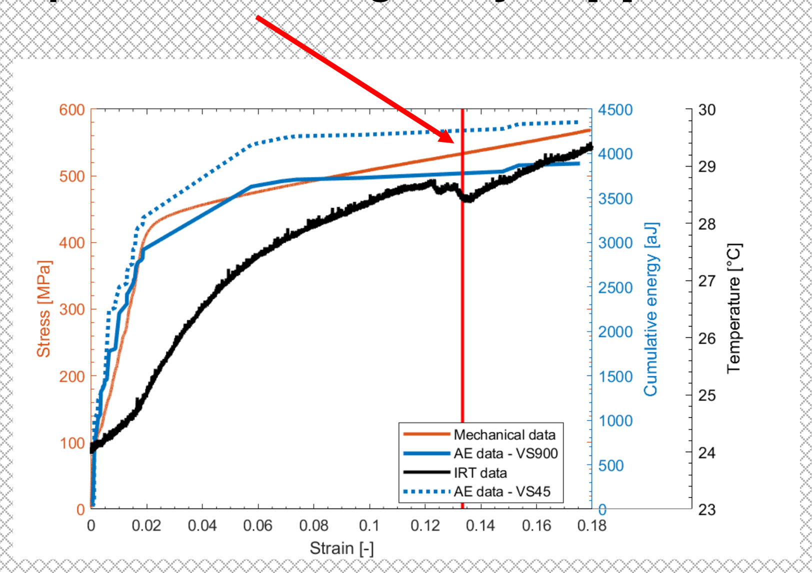
Results II.

Deformation up to 18 %

Critical stress for twinning computed according to Byun [5]



$\dot{\varepsilon} = 7x10^{-4}s^{-1}$
Nearly linear temperature increase continues even after potential occurrence of twinning



$\dot{\varepsilon} = 1.4x10^{-4}s^{-1}$
Temperature increase drop with the onset of twinning

Conclusions

- **AE with IRT showed a good applicability as the in-situ NDE techniques for low strain structural changes investigation.**
- **Increase in maximum temperature with progressive deformation shows nearly linear character at $\dot{\varepsilon} = 7x10^{-4}s^{-1}$ which is most likely the rate where $Q_{generated} = Q_{dissipated}$ for an investigated stainless steel.**
- **Creation of Shockley partials and formation of stacking faults possibly correspond to the area of steep increase in AE cumulative energy which is consistent with the area of slow maximum temperature changes.**
- **At the rates below $\dot{\varepsilon} = 7x10^{-4}s^{-1}$:**
  - **Shear bands and ε-martensite transformation can be possibly detected as an area of nearly monotonous concave rise of maximum temperature and decelerated increase of AE cumulative energy;**
  - **The onset of twinning is manifested as a drop/disturbance of monotonic temperature increase.**

[1] E. I. Galindo-Nava a P. E. J. Rivera-Díaz-del-Castillo, *Acta Materialia* , pp. 120-134, 2017.
[2] X. Li, J. Chen, L. Ye, W. Ding and P. Song, *Acta Metallurgica Sinica, 26*, pp. 657-662, 2013.
[3] Y. F. Shen, X. X. Li, X. Sun, Y. D. Wang and L. Zuo, *Materials Science and Engineering A 552*, pp. 514-522, 2012.
[4] B. Kozlowska, *The Archives of Mechanical Engineering*, 59(3), pp. 297-312, 2012.
[5] T. S. Byun, *Acta Materialia 51*, pp. 3063-3071, 2003.