Study on Thermomechanical Treatment, Mechanical Properties and Fatigue of Nitinol Superelastic Thin Sheet

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Agenda:

- **Introduction**
- **Experimental**
- **Mechanical Data & Fatigue**
- **Conclusions**

Introduction

- Nitinol in thin sheet form is gaining relevance in the market place:
  - Mass products successful such as Abbott StarClose™ and 3M SmartClip
  - More design variants for engineers
  - Possibility for OEMs to differentiate
  - New/different manufacturing processes, e.g. photochemical etching, stamping, deep drawing

Introduction

- Nitinol sheet consumption is growing:
  - We expect today about 7‘500 lbs worldwide
  - Still small if compared to Nitinol tube (ca. 100‘000 lbs)
  - Number of vendors increases → competition + price pressure increase:
    - Nitinol tubing: ca. 12 manufacturers wordwide
    - Nitinol thin sheet: ca. 4 manufacturers worldwide

4

Introduction

Purpose of this Paper:

- Paper investigates the effect of thermomechanical treatments on the properties (mechanical, thermal, fatigue) of Nitinol thin sheet.
- Special emphasis is put on the effect of sheet anisotropy on mechanical properties

Sample manufacturing carried out at Memry GmbH/D

Tensile testing, DSC & Fatigue testing carried out at Admedes GmbH

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Experimental

Preparation of Sample Matrix:

- 3 different CW
- 5 different annealing temperatures
- 3 different annealing durations
- Sample orientation in 0° (RD), 90° (TD) and 45° to rolling direction
- Final sheet thickness constant (0.3 mm)

Experimental

Sample Matrix:

Parameter	Value
Cold Work	25% - 30% - 35%
Heat treatment temperature	480°C – 495°C – 510°C – 525°C – 540°C
Heat treatment duration	3 min. – 3 + 8* min. – 3 + 28* min.
Sample orientation	RD – TD – 45°

*: time in air convection furnace after flat annealing

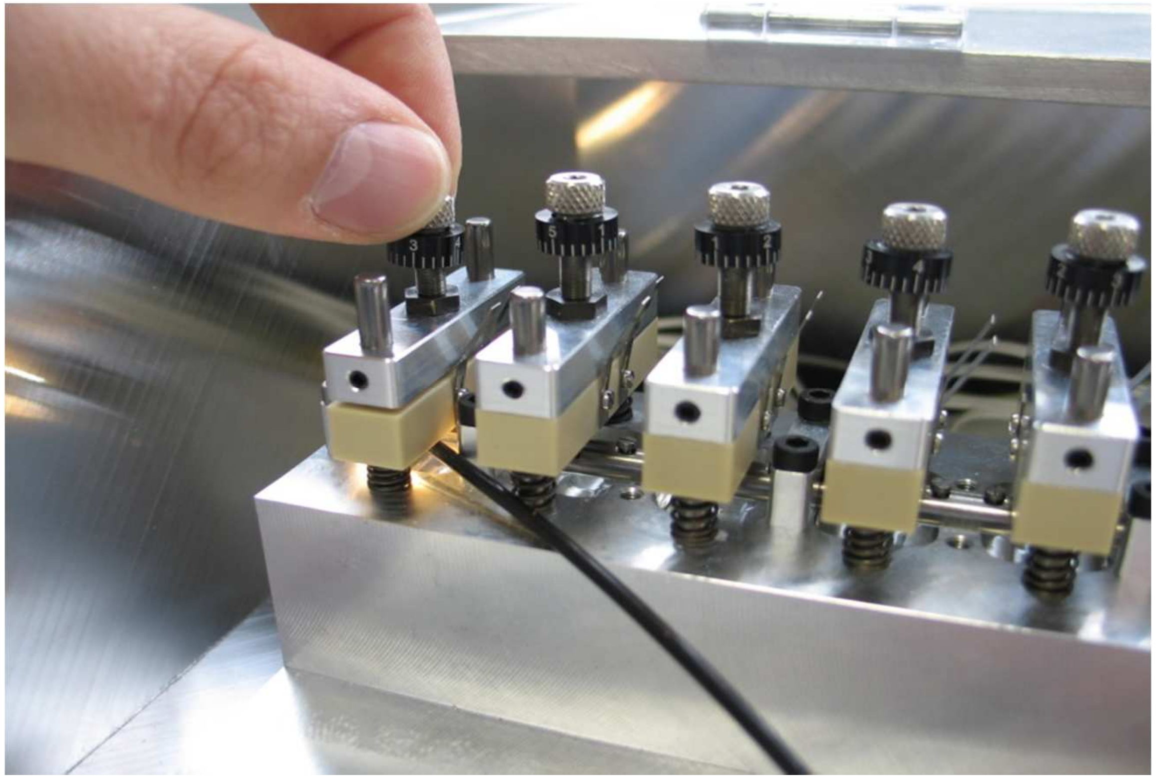
Experimental

Test Matrix:

- Tensile testing (T = 37°C) →ASTM F2516
- DSC testing →ASTM F2004
- Bend-and-Free recovery testing (BFR) →ASTM F2082
- Fatigue testing (T = 37°C)

Experimental

Fatigue Tester:



Admedes Fatigue Tester:

- 3-point bending mode
- Air convection
- High frequency (60 Hz)
- 10 identical samples
- Test stop when fracture occurs

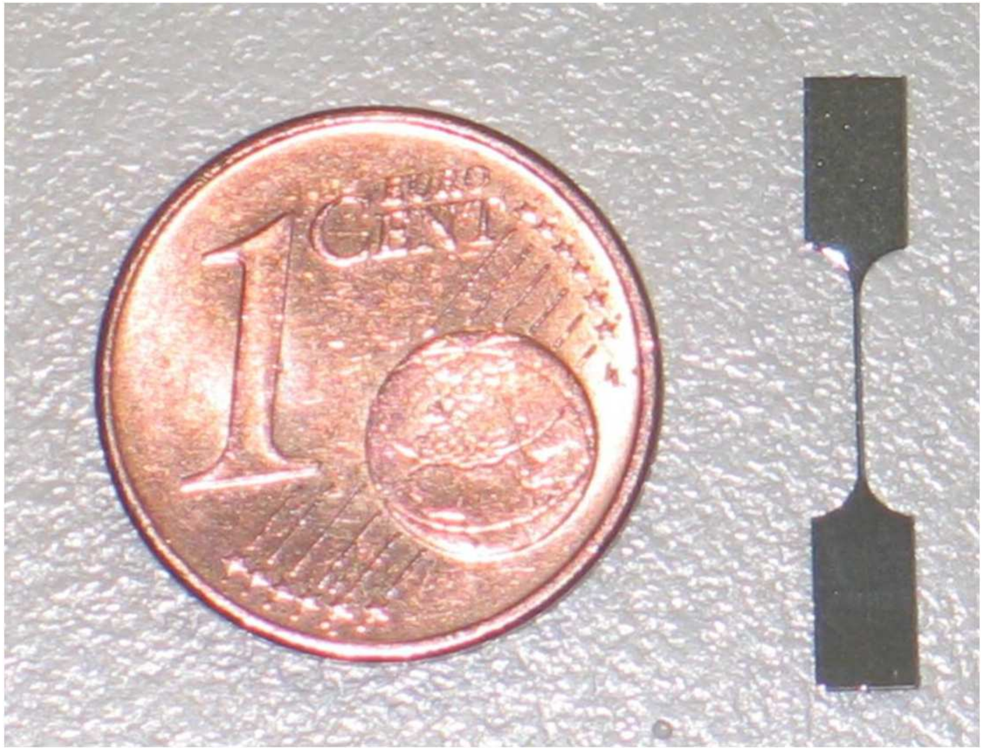
Experimental

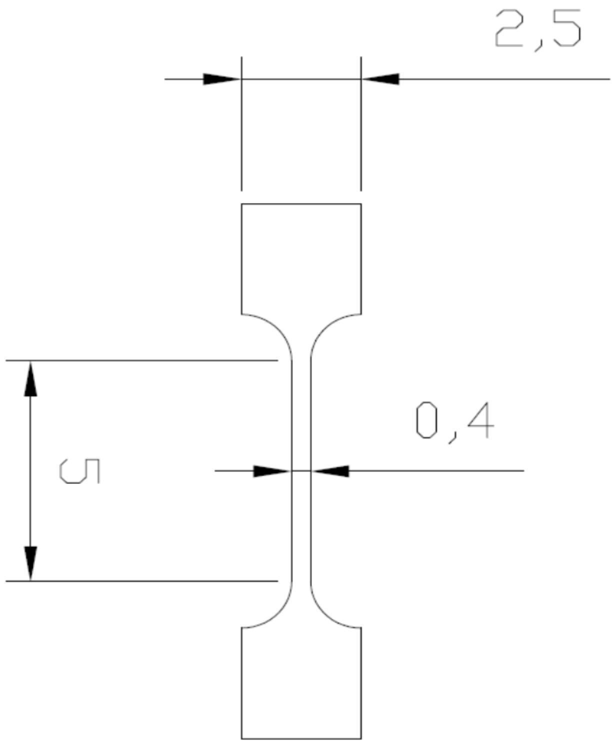
Sample preparation:

- Laser cutting of μ-Dogbones
- Deburring
- EP surface finish

11

Experimental





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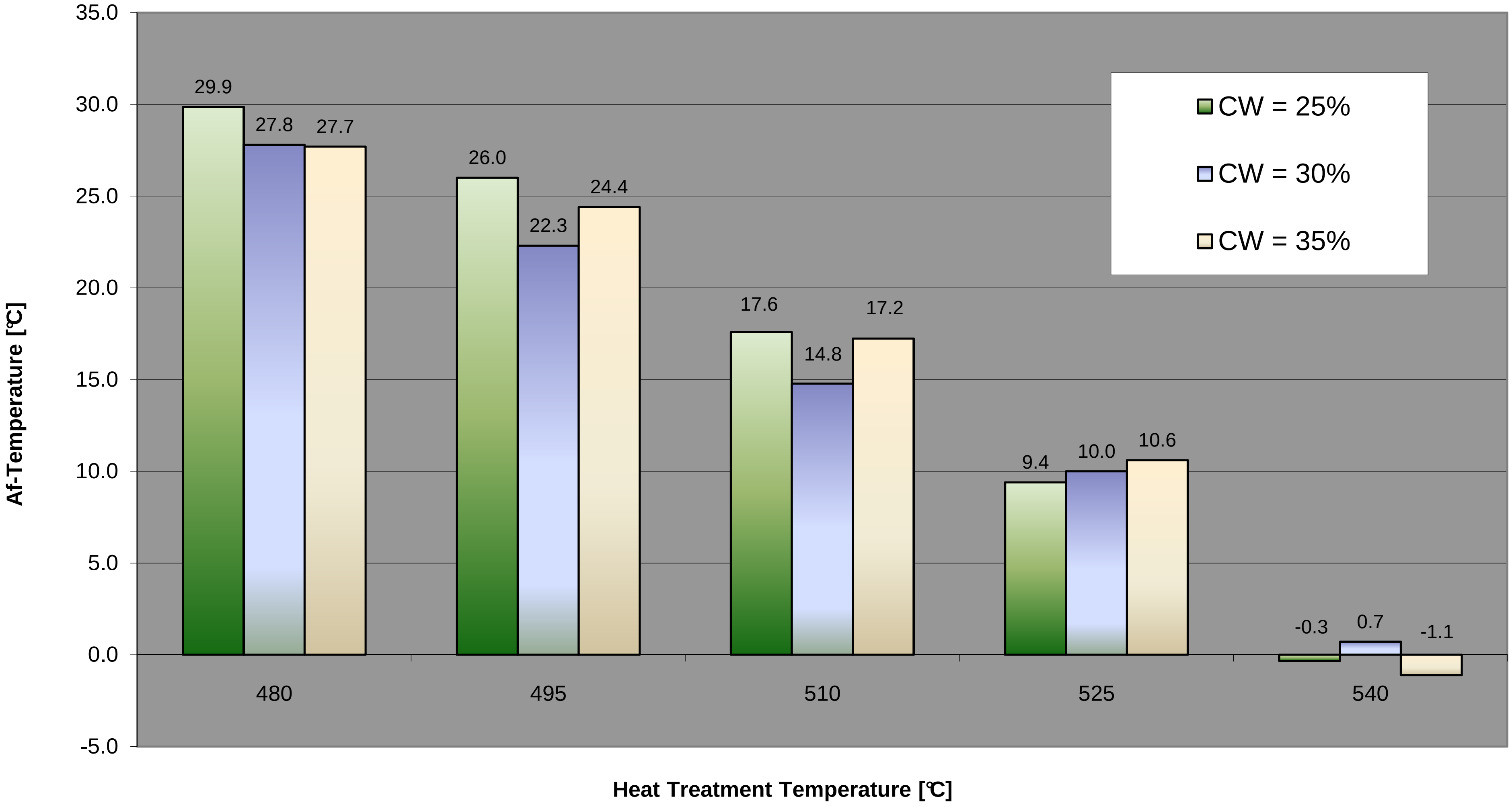
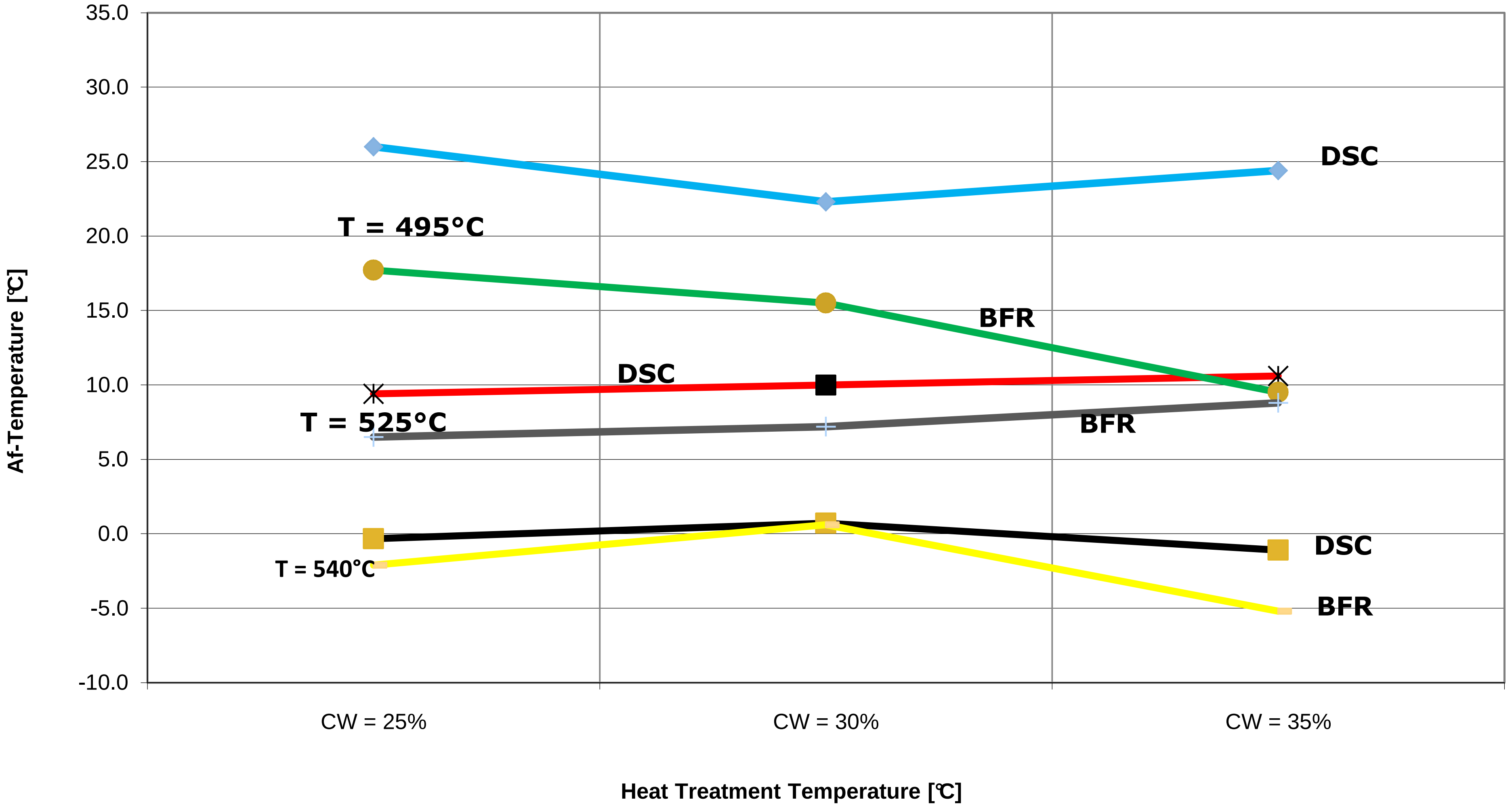
13

Results: DSC & BFR



14

Results: DSC & BFR

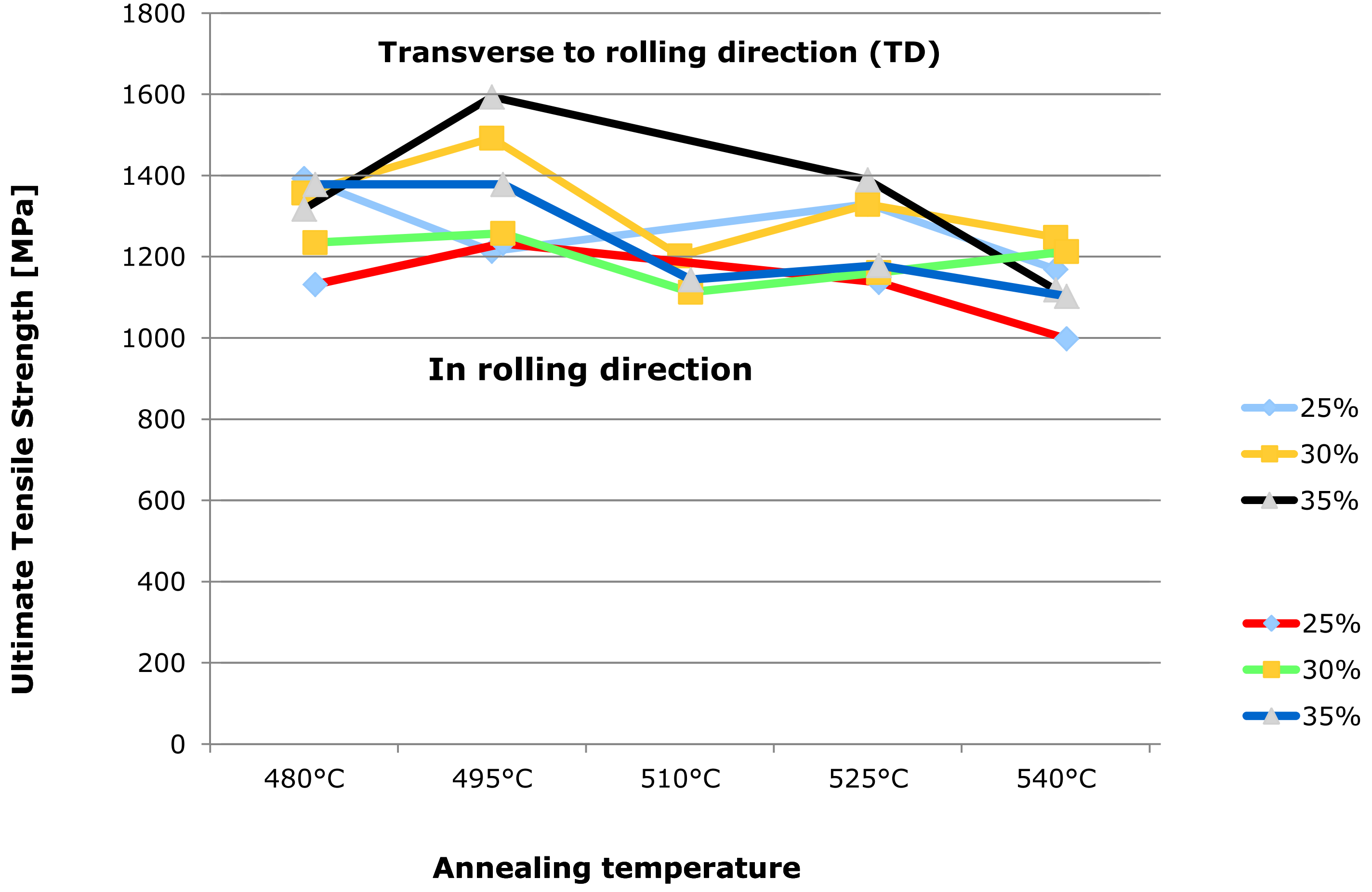


Results: DSC & BFR

Key Findings:

- DSC results were in line with data collected from wire with similar test parameters
- Differences between the investigated CW-% were minor/insignificant
- Correlation between DSC and BFR acceptable only for higher annealing temperatures

Results: Tensile Tests



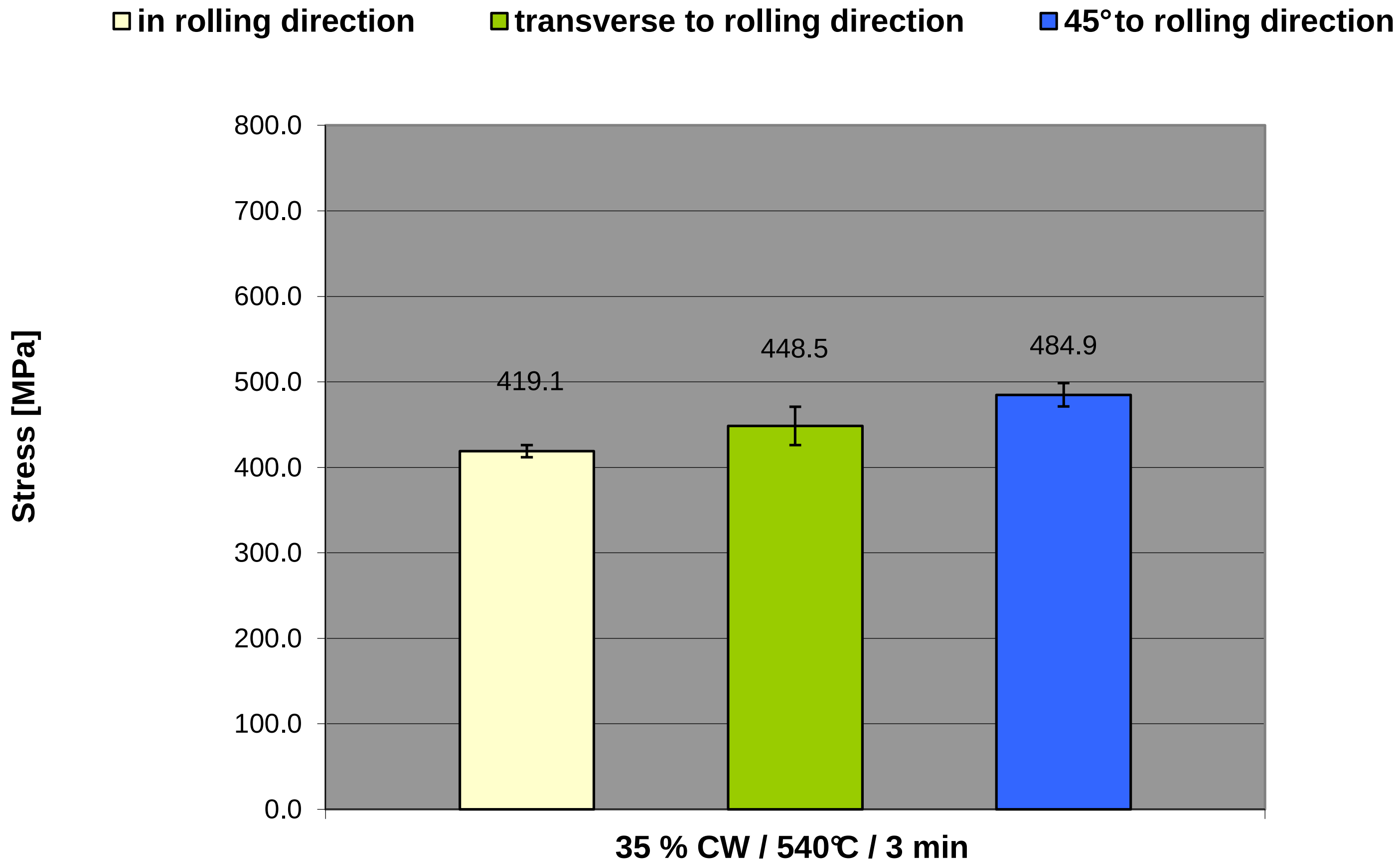
Results: Tensile Tests

Key Findings:

- UTS values tend to be higher for TD as compared to RD → smaller grain size
- Plateau stresses tend to be higher in TD. Most likely: energy level to activate martensite variants is different in different crystallographic orientations
- 45° orientation shows highest plateau stresses!

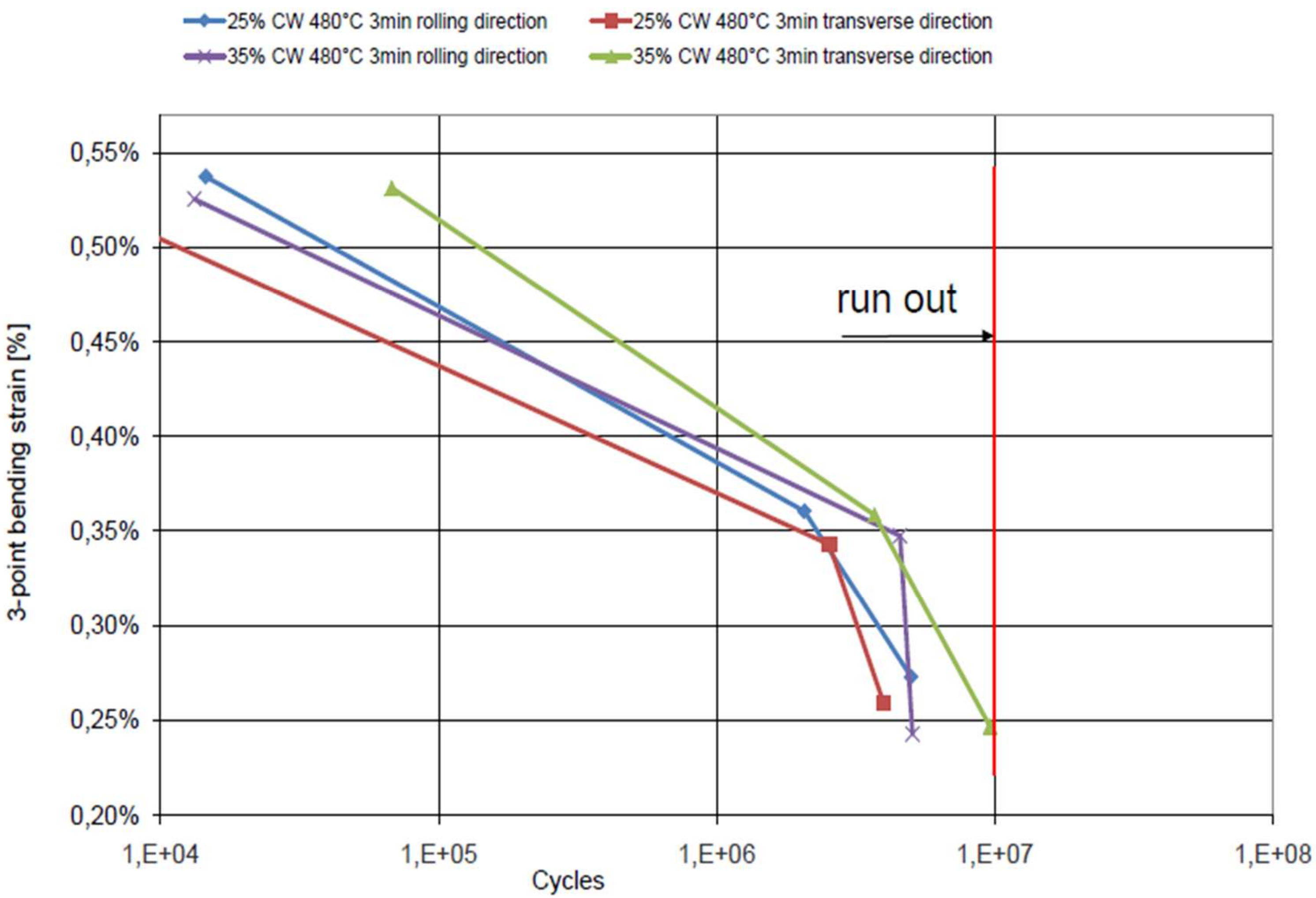
Results: Tensile Tests

Upper Plateau Stress vs. Sample Orientation



19

Results: Fatigue Tests



Results: Fatigue Tests

Key Findings:

- 3-point bending fatigue tests did generate only few run-outs
- No clear difference between TD and RD!
- High test frequency eventually affected the test results

Conclusions

Key Takeaways:

- Results on Nitinol thin sheet are similar to wire/tube
- UTS in TD higher than in RD
- Plateau in 45°C higher than RD/TD
- DSC does not show big effect of CW on Af

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