Investigation of surface damage caused by multiple laser-induced single bubble cavitation

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Motivation

- Most fundamental studies of cavitation damage formation are carried out on soft materials such as aluminum.

- Cavitation erosion on technical alloys is typically investigated with acoustic cavitation.

- Almost no work with single bubbles on technical alloys.

- It is not clear whether the same damage mechanisms apply to technical as to softer materials.

Experimental set-up: Bubble generation and detection

- Generation of bubbles with laser focus of 1064 nm Nd:YAG Laser
- Bubble dynamics are captured with a high-speed camera
- Ex-situ confocal and white light microscopy analysis
Materials

**X2CrNiMo18-15-3 (316L©)**
- \( R_{\text{yield}} \geq 190 \, \text{MPa} \)
- \( R_{\text{tensile}} = 490\text{-}690 \, \text{MPa} \)
- hardness = 132 ± 4 HV10

**X13CrMnMoN18-14-3 (P2000©)**
- \( R_{\text{yield}} \geq 600 \, \text{MPa} \)
- \( R_{\text{tensile}} \geq 900 \, \text{MPa} \)
- hardness = 271 ± 7 HV10
- contains ≈ 0.8 wt.% N

**CuAl10Ni5Fe5 ("NAB")**
- \( R_{\text{yield}} \geq 280 \, \text{MPa} \)
- \( R_{\text{tensile}} \geq 650 \, \text{MPa} \)
- hardness = 275 ± 11 HV10
Ex-situ analysis of multi-bubble damage

- Maximum depth of the damage region is measured

- Ex-situ damage analysis
  - new sample for each data point

- Fluctuations are not physical
  - in-situ operando imaging of damage evolution

In-situ experiments

- Incident-light microscope to investigate surface damage in situ
- Entire damage process can be observed in one single sample
- Increasing intervals between successive microscope images
L316 Steel – $\gamma = 1.4 \ r = 1.3 \ mm$

Side view

Top View

beam direction
Damage formation at $\gamma = 1.4$

Steel – 5850 bubbles

Aluminum – 100 bubbles

Steel – 5000 bubbles

NiAl-Bronze - $\gamma=1.36$ r=1.25 mm

Side view

beam direction

Top View

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L316 Steel  $\gamma = 1.3$  $r = 1.25$ mm

beam direction
Conclusions

- In-situ microscopy allows following the damage process step by step

- Even technical alloys show first damage after just a few cavitation bubbles

- For gamma $\gamma \approx 1.3 - 1.4$ this damage occurs in small individual pits, each in the area of the second collapse

- Next: Correlation with more detailed ex-situ analysis, parameter variations