Institute of Test and Simulation for Gas Turbines, German Aerospace Center (DLR SG)

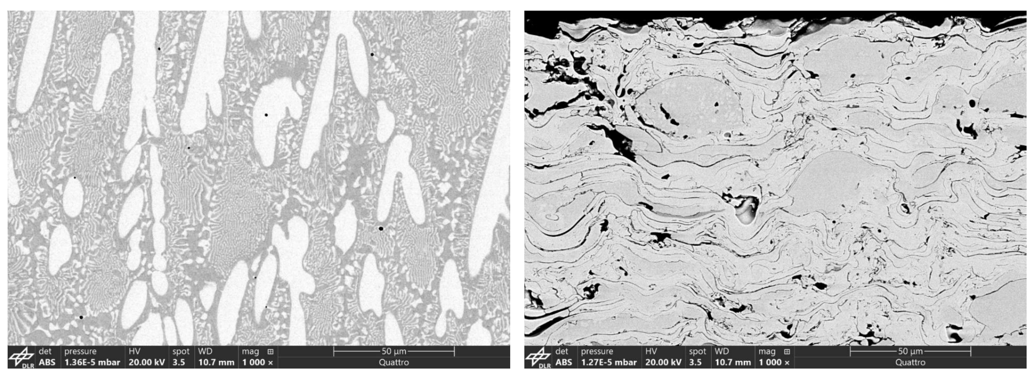
High-temperature fretting wear behaviour of cobalt alloys

Motivation

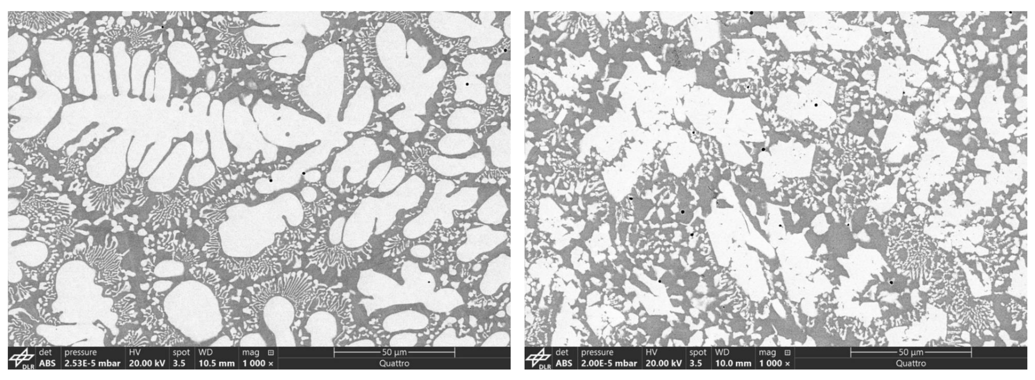
Cobalt-based alloys are often used for components subject to high thermal and mechanical loads in corrosive environments where relative motion with small amplitudes occur. Use cases include parts and coatings at the turbine blade/disk interface, turbine blade shroud coatings, cast guide vane components as well as valve seat inserts in internal combustion engines and biogas generators.
The friction and wear properties of the established Tribaloy™ alloys T-400, T-800 and a next generation high-entropy alloy with reduced cobalt content were investigated under ambient air atmosphere up to 700 °C using the SRV®5 tribometer (*Optimol Instruments Prüftechnik GmbH*) fitted with the designated high temperature block.
Analysis of the specimens include wear scar volume determination, scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDS).

Materials

- Hypereutectic Tribaloy™ T-400 and T-800
- Cast and HVOF-coated (high velocity oxygen fuel) T-400 disks
- Newly developed high-entropy alloy / next generation Tribaloy™ (cast)
- Intermetallic Laves-phases embedded in softer eutectic matrix



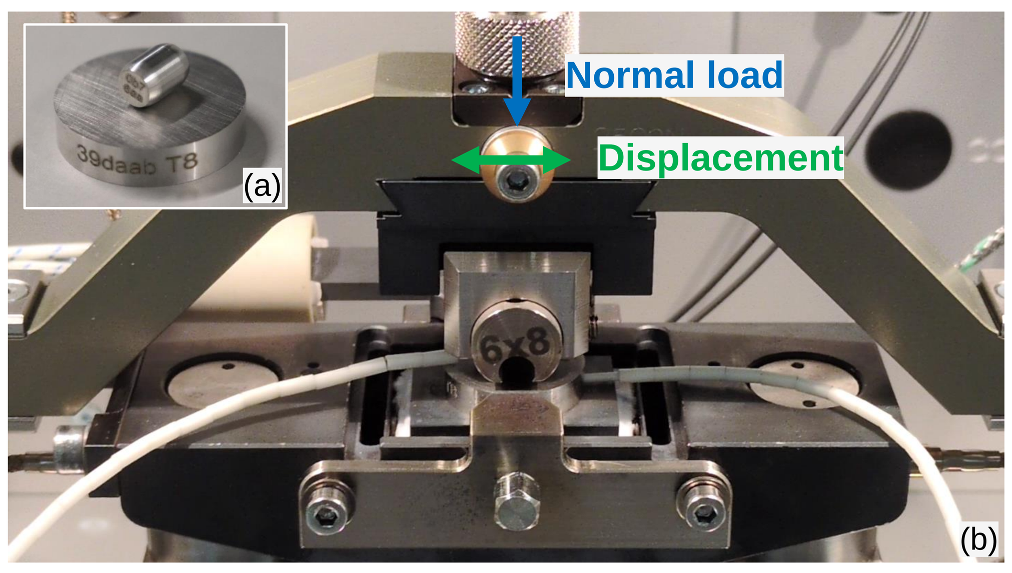
T-400 cast (l.) and HVOF-coated (r.), 1000x



T-800 (l.) and new high-entropy alloy (r.), 1000x

Fretting wear tests

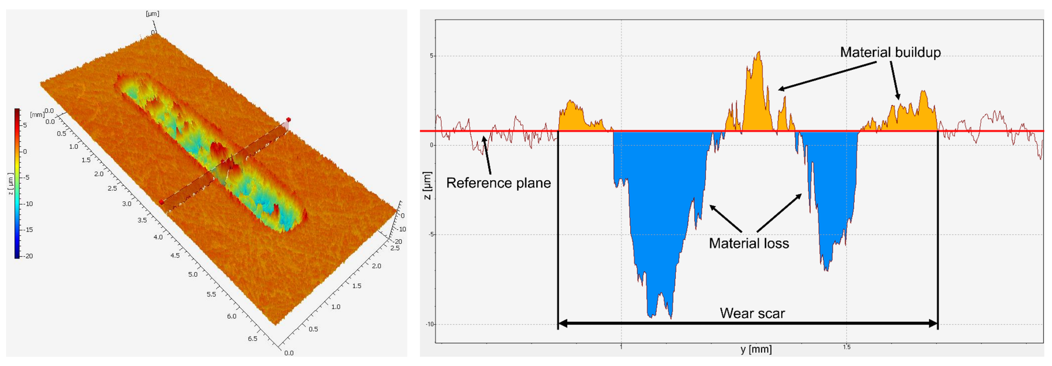
- Cylinder-on-disk contact configuration
- Unlubricated test condition
- Normal load: 100 N → 570 MPa initial Herztian contact pressure at 22 °C
- Test frequency: 25 Hz, 50 Hz
- Displacement amplitude: 150 µm, 300 µm
- Duration: Up to 500 000 cycles
- Temperature: 200 – 700 °C, thermocouple welded to disk surface for temperature measurement and control



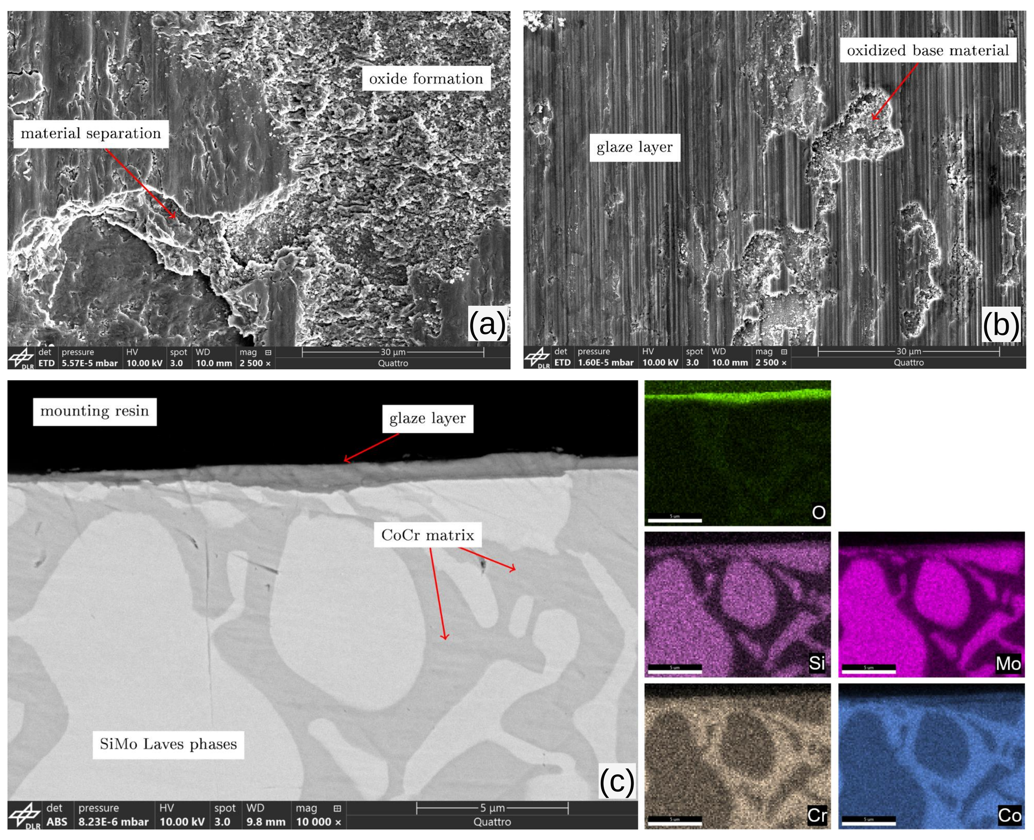
Cylinder and disk specimen (a), experimental setup (b)

Analysis of wear scars

- Light microscopy, SEM and EDS analysis of specimen surface and cross sections
- Surface topography measurement of wear scar using white light interferometry (WLI)
- Volumetric wear V_w calculated as volume of lost material minus volume of buildups



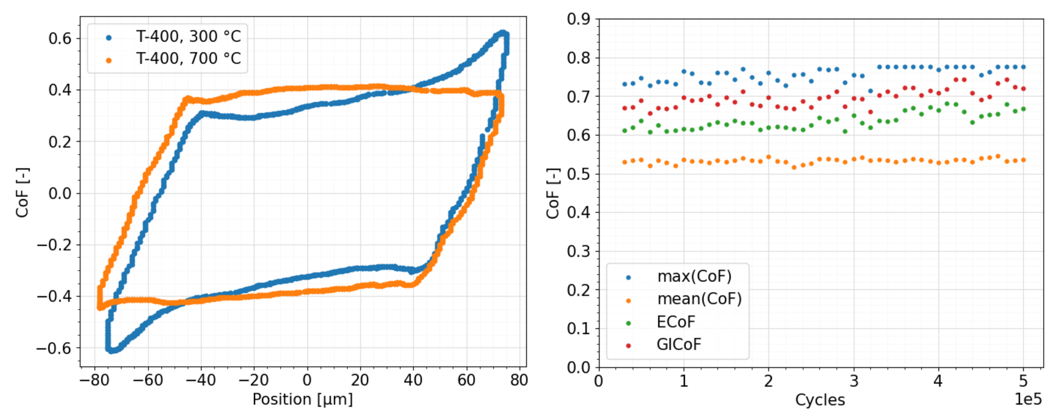
Wear scar topography (l.), calculation V_w (r.)



Wear scars on T-400 disks, 400 °C (a), 700 °C (b), cross section of glaze layer (c)

Analysis of friction behaviour

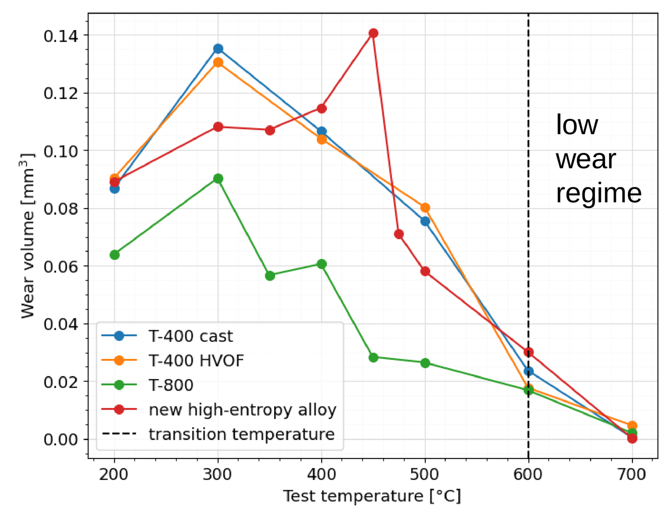
- Cycle based evaluation of coefficient of friction (CoF) based on HRA data (high resolution analysis)
- CoF calculation using different methods: max(CoF), mean(CoF), ECoF and GICoF



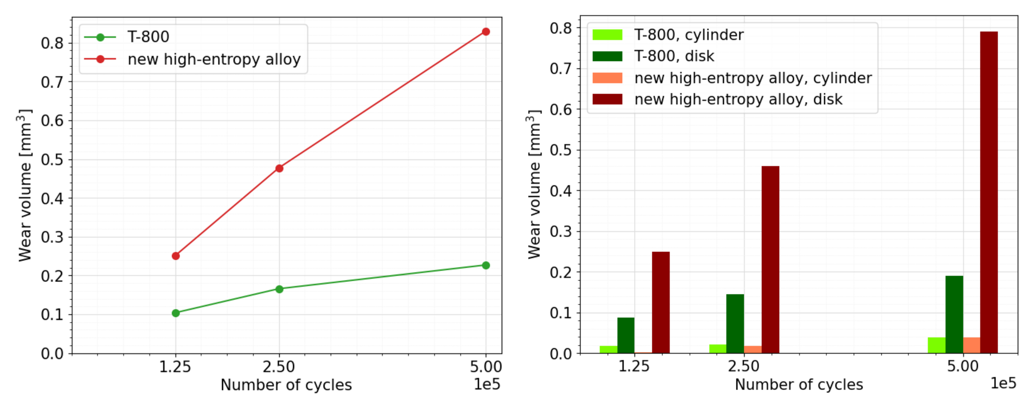
Fretting loops for T-400 at 300 and 700 °C (l.), calculated CoF values for one testrun (r.)

Comparison of wear behaviour

- System wear consisting of cylinder and disk wear volume
- 300 – 450 °C: High system wear
- Similar system behaviour of cast and HVOF-coated T-400 alloys
- Glaze layer formation on all alloys (approx. 1 µm thick)
- Low wear regime above approx. 600 °C



System wear at 200 – 700 °C (150 µm, 50 Hz, 500 000 cycles)



System wear at 400 °C (300 µm, 25 Hz) (l.), wear volumes of cylinder and disk for T-800 and the new high-entropy alloy (r.)

Conclusion

- Similar wear behaviour for all investigated alloys between 600 and 700 °C
- Wear reducing glaze layer observed at high-temperatures for both established Tribaloys™ and the new high-entropy alloy

Outlook

- Increase of test temperature up to 850 °C, application temperature of new high-entropy alloy starting at 700 °C
- Detailed analysis of glaze layer using X-ray diffraction (XRD)
- Application of wear models to test data
- Influence of synthetic combustion gases (N_2, O_2, CO_2, SO_2, NO_x, H_2O vapour)

Contact: J. Walz (johannes.walz@dlr.de), Dr. N. Kind (nora.kind@dlr.de)
Institute of Test and Simulation for Gas Turbines
Department Testing and Measurement Techniques (TMV)
Mechanical-Thermal-Chemical Testing (MTC)

Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Center