SFB 483: Silicon Nitride based Ceramic Wire Rolling Tools

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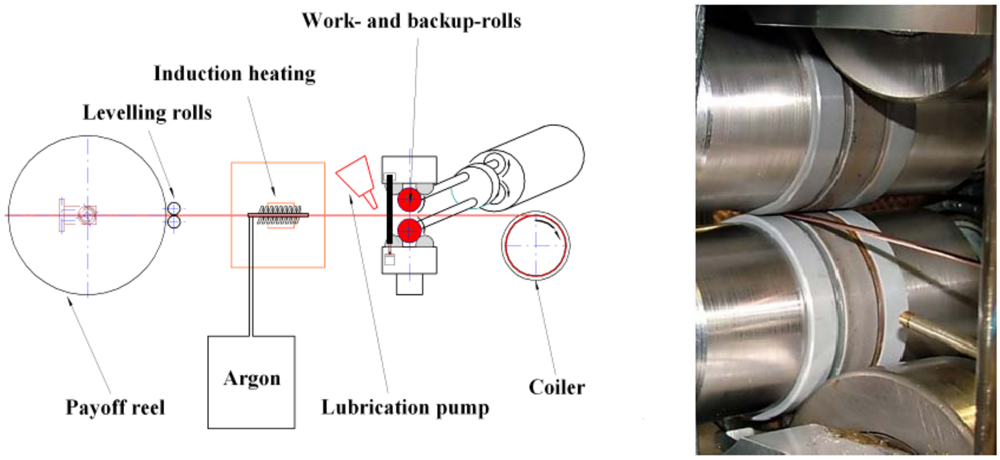
This project is part of the *DFG SFB-483* program *"High performance sliding and friction systems based on advanced ceramics"*; and is leading the "Rolling Systems" workgroup. This workgroup investigates the failure mechanisms of ceramic wire rolling tools for the rolling of high purity copper and high strength steel. Our subproject's aim is to experimentally validate the outcome of experimental and numerical analyses conducted by the other subprojects or systems tests. A system-oriented model for the failure mechanisms of silicon nitride should help to understand the capabilities and limitations of silicon nitride as wire rolling tools.

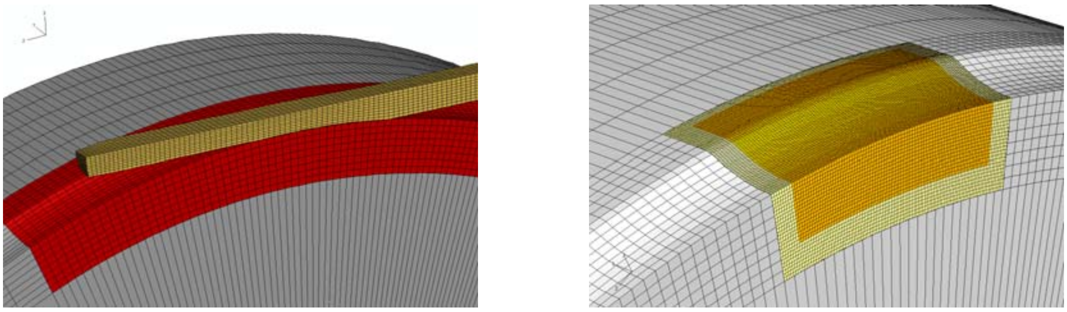
First the wire rolling test rig at Fraunhofer IWM in Freiburg was modified and adjusted for running wire rolling experiments at several working temperatures using ceramic rolls
(Fig. 1a and b).



(a) (b)

Fig. 1: (a) Wire rolling test rig, (b) work rolls are arranged in a cluster mill configuration

Finite element models were constructed and run to simulate wire rolling using ceramic work rolls (Fig. 2a). Coupled thermomechanical loading was taken into consideration when modeling the system. The simulations were run using ABAQUS/Explicit dynamic temperature displacement analysis. The models were adapted to simulate several wire materials, operating parameters and loading conditions. The simulation results provide the input data to conduct reliability analyses via STAU in subproject C4 of the workgroup
(Fig. 2b).

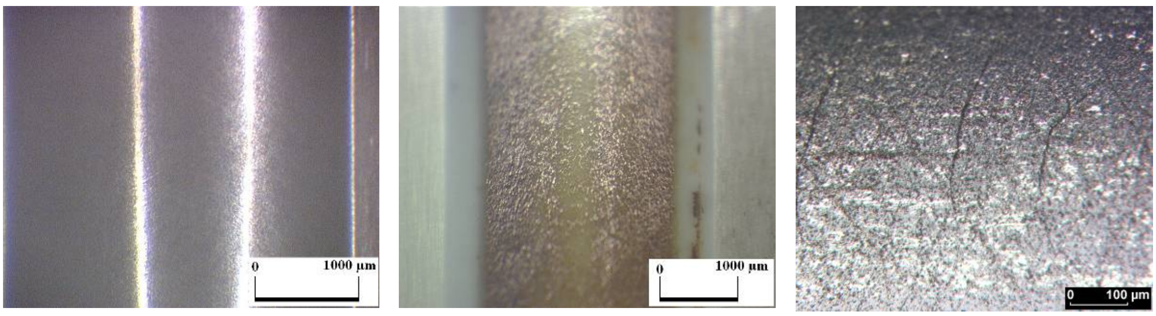


(a) (b)

Fig. 2: (a) Wire rolling 3-D FE mesh, (b) element set provided FE data to run reliability analysis in STAU

Wire rolling experiments were carried out using high purity copper (CU-OF1) and high strength steel (1.4310) wires on silicon nitride work rolls (Fig. 1b). The experiments were run under dry and lubricated conditions. After conducting the experiments, the rolling surfaces were inspected under the light microscope, the scanning electron microscope (SEM/EDX) and the stylus profilometer.

Rolling copper wire showed considerable metallic adhesion on the surface of the ceramic rolls (compare 2a and 2b). The formation of metallic layers was significantly reduced by applying water-based emulsion lubricants.



(a) (b) c)

Fig. 3: (a) Caliber surface before running the experiments, (b) copper adhesion on the caliber surface, (c) surface cracks on the caliber

Slight wear rates were detected on the surface of the rolls after running the experiments. Material stresses calculated in FE-simulations showed values too low to cause damage to the rolls. On the other hand, shear stresses significantly affected the locations and severity of metallic adhesion.

Rolling experiments, carried out at room temperature using steel wire, showed formation of surface cracks on the silicon nitride rolling calibers (3c). FE-simulations showed that the developed shear stresses are high enough to contribute to the formation of surface cracks. Thermal stresses were found to form only a minor fraction of the overall thermomechanical stresses. The density of crack formation, under the same loading conditions, considerably increased under water lubrication in comparison to water-based emulsion lubrication.