PROZESS SIGNATUREN

TRANSREGIONALER SONDERFORSCHUNGSBEREICH 136

Universität Bremen · RWTH Aachen University · Oklahoma State University · kks Lehrstuhl für Korrosion und Korrosionsschutz · RWTH Aachen University

Mechanism Analysis of Machining-Induced Chemical Material Modifications and their Effect on the Component Functionality

Subproject M06 – Prof. Dr.-Ing. Daniela Zander

Objective and approach

The subproject M06/Reaktionsmechanismen addresses three overall research goals:

- mechanistic analysis of material removal on 42CrMo4 steel for manufacturing processes with chemical impact: ECM (electrochemical machining, F03) and LCM (laserchemical machining, F07)
- quantification of chemical loads and rim zone modifications for ECM and LCM
- investigation of the influence of the rim zone properties modified by ECM and LCM on the functionality of the surface (resistance to high-temperature corrosion in oxygen-containing atmospheres)

Current state of knowledge

Material removal during ECM and LCM has been extensively studied mechanistically. ECM is based on the anodic dissolution of the metallic workpiece in the electrolyte, which is caused by the application of an external transpassive voltage. Dissolution occurs via the intermediate step of oxide layer formation, whose composition and structure depend significantly on the current density and voltage in the process, as shown in **Fig. 1**. [1] The oxide layer, along with the microstructure of the 42CrMo4 steel, is an important factor influencing the efficiency of material removal and the resulting rim zone properties. [3,4] The removal mechanism in the LCM process is complex and, depending on the material-electrolyte combination, can be based on thermobattery as well as on the increase of corrosion current density, destruction of passive layers and partial melting of the material. However, for the machining of 42CrMo4 in $NaNO_3$ solution, thermobattery was excluded as a removal mechanism.

In addition to the understanding of material removal mechanistics, a quantification of the (electro-)chemical loads and the chemical rim modifications in the ECM process as well as in the LCM process has also been carried out. The quantification of loads and modifications could be used to establish process signature components, as exemplified for the ECM process in **Fig. 2**.

Furthermore, it has been successfully demonstrated in preliminary investigations that the process-induced changes in the rim zone properties lead to a change in the functionality of the material. This has been determined for the example of high-temperature corrosion in oxygen-containing atmospheres for both ECM [2] and LCM machined 42CrMo4 steel.

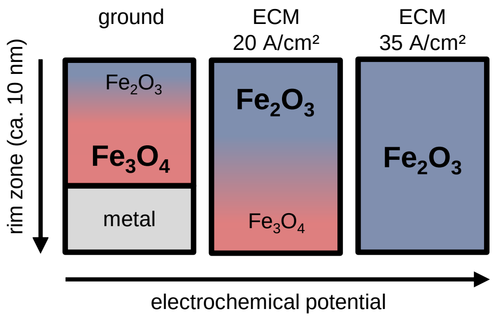

Figure 1: Structure of the oxide on 42CrMo4 after ECM in $NaNO_3$ solution.

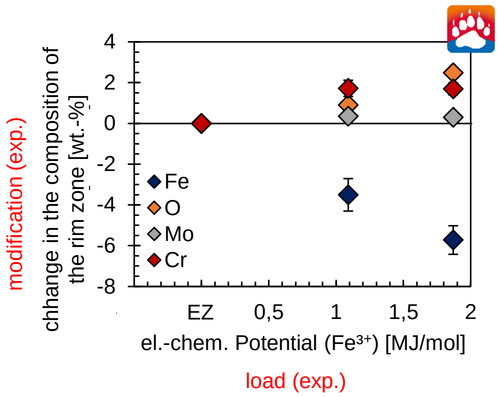

Figure 2: Process signature for ECM in $NaNO_3$ solution.

Conclusions and further procedure

Significant correlations between the (electro-)chemical loads occurring in the machining process and the rim zone properties have been identified. These results could be used to decipher the reaction mechanisms occurring in the process.

In addition, the influence of the rim zone properties "residual stresses", "topography/roughness" and " rim zone chemistry" on the functionality of the surfaces was investigated. For this purpose, the resistance of materials to high-temperature corrosion in oxygen-containing atmospheres was investigated as a functional property. These investigations are currently being systematically continued in order to reveal the oxidation mechanisms.

Publications

[1] Zander; Schupp; Rommes; Klink; Beyß: Oxide formation during transpassive material removal of martensitic 42CrMo4 steel by electrochemical machining. Materials (2021) 14(2), 402. https://doi.org/10.3390/ma14020402

[2] Zander; Klink; Harst; Klocke; Altenbach: Influence of machining processes on rim zone properties and high temperature oxidation behavior of 42CrMo4. Mater. Corros. (2019) 70, 2190–2204. https://doi.org/10.1002/maco.201910928

[3] Zander; Schupp; Mergenthaler; Pütz; Altenbach: Impact of rim zone modifications on the surface finishing of ferritic-pearlitic 42CrMo4 using electrochemical machining. Mater. Corros. (2021), 1–15. https://doi.org/10.1002/maco.202012213

[4] Schupp; Zander; Beyß; Rommes; Klink: Insights on the influence of surface chemistry and rim zone microstructure of 42CrMo4 on the efficiency of ECM. Materials (2021) 14(9), 2132. https://doi.org/10.3390/ma14092132