

Processes with thermo-mechanical effect – Finishing processes

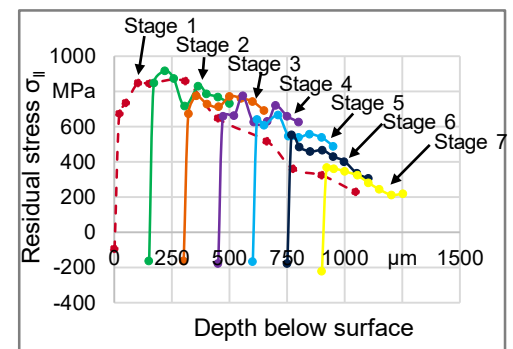
Subproject F06 – Prof. Dr.-Ing. habil. Carsten Heinzel, Dr.-Ing. Daniel Meyer

Objective and approach

The loads occurring during the grinding process are composed of different intensities of thermal and mechanical loads depending on the selected system and control variables. The resulting material modifications must therefore always be considered in the context of the combined thermo-mechanical loads. In order to obtain a mechanism-based understanding of this interaction, the combined laser and deep rolling process is investigated in addition to the grinding processes. With this analogy process, the load due to the thermal load (by the laser machining) and the load due to the mechanical load (by deep rolling) are to be varied independently of each other. Thus, the interactions between the thermal and mechanical loads will be investigated and the resulting material modifications will be related to them, and finally a process signature component for thermo-mechanical processes will be established. A specific focus in the grinding investigations is also on multi-stage machining. In this context, the depth effect in particular is another important aspect to be investigated in the expansion of the load fields during grinding.

Current state of knowledge (May 2021)

For multi-stage grinding of hardened 42CrMo4, the grinding process in a first grinding stage was designed to significantly influence the residual stresses below the surface. Stages 2-7 had no influence on the residual stresses below the surface. Since the depth profiles of the residual stresses after stages 2-7 followed the profile from stage 1, it can be assumed that with this application-oriented process control there was a relevant change in the material properties at different workpiece depths as a result of the material modification after the first grinding stage. For grinding and combined laser and deep rolling, it was also possible to establish process signature components that use the maximum temperature gradient as the load and the residual surface stresses as the modification.



Influence of multi-stage grinding on the residual stress depth profile

Conclusion and further procedure

The determined modifications after the multistage grinding process are a product of the load collective as a result of the thermal and mechanical load. Crucial for a complete understanding of the loading effect is the knowledge of how far the load collective changes when the mechanical or thermal load is varied. The design of the combined laser and deep rolling process, which was developed for this purpose, has already produced results which suggest that there is an optimum temperature range which has a positive effect in the edge zone when residual compressive stresses are established. A focus of the following investigations will also be the consideration of the depth effect of thermo-mechanical stresses and modifications for multi-stage thermo-mechanical processes.

Publications

- [1] B. Kolkwitz, E. Kohls, C. Heinzel, E. Brinksmeier, "Correlations between Thermal Loads during Grind-Hardening and Material Modifications Using the Concept of Process Signatures", *Journal of Manufacturing and Materials Processing*, vol. 2, no. 1, p. 20, <http://dx.doi.org/10.3390/jmmp2010020>.
- [2] E. Brinksmeier, D. Meyer, C. Heinzel, T. Lübken, J. Sölter, L. Langenhorst, F. Frerichs, J. Kämmeler, E. Kohls, S. Kuschel, "Process Signatures - The Missing Link to Predict Surface Integrity in Machining", *Procedia CIRP*, vol. 71, 2018, pp. 3-10, <https://doi.org/10.1016/j.procir.2018.05.006>.
- [3] E. Kohls, R. Zmich, C. Heinzel, D. Meyer, "Residual stress change in multistage grinding", *Procedia CIRP*, vol. 87, 2020, pp. 186-191, <https://doi.org/10.1016/j.procir.2020.02.068>.
- [4] C. Heinzel, J. Heinzel, N. Guba, T. Hüsemann "Comprehensive analysis of the thermal impact and its depth effect in grinding", *CIRP Annals*, vol. 70-1, 2021.