IMPROVEMENT OF MACHINING QUALITY THROUGH GEAR HONING BY OPTIMIZING THE MAIN SPINDLE DRIVE DYNAMICS

Peter Langenstein [(a)], Urs Meyer[(b)] and Konrad Wegener [(c)]

[(a)] Fässler AG, Ringstrasse 20, CH-8600 Dübendorf
[(b)] Institute for Manufacturing Automation, ETH Zurich, Clausiusstr. 1, CH-8092 Zürich
[(c)] Institute of Machine Tools and Manufacturing, ETH Zurich, Tannenstr. 3, CH-8092 Zürich,

Gear honing is an abrasive fine-finishing process for hardened gears, which is applied mainly to gears for high-performance transmission systems. Its main advantages are the improvement of the tooth shapes of work wheels in the direction of the tooth profile and of the gear flanks, and the development of a low-noise surface structure on the flanks. The introduction of an electronic coupling between the tool spindle and the work piece spindle is intended to correct the long-wave cumulated pitch error and the associated long-wave contribution of the kinematical transmission error.

The generation and removal of the work piece waviness during honing, which affect the work piece as kinematic transmission errors, have previously not been investigated in relation to gear honing. This made it necessary not only to design the control system for the coupled spindles, but also to develop a model for the process dynamics.

This model consists of two parts. The first part describes the dynamics of the machine and of the transmission systems coupled by the process, and allows to estimate the dynamic process forces and the displacements for a given work piece waviness. The second part of the model covers the development of the transmission error in the work piece during the machining process, and establishes a relationship between the local metal removal on the work piece and the active process force.

Practical experiences revealed that the overall system behavior is characterized by the transfer function between the normal process force and the transmission error of the work piece. The stability of the process is mainly given by the phase of the transfer function for frequencies multiple to the work piece frequency. Important phase angle lags lead to an instable process, while small phase lags guarantee a stable process. That means that the amplitude of work piece waviness decreases quickly, following an exponential law.

As a consequence, the machining quality can be improved by optimizing the controller for the tool and the work piece spindles. Therefore, different controller configurations have been evaluated and compared. Best results can be achieved by using high gain, high bandwidth controllers resistant to dynamic and periodic disturbances. In order to control the static processing force a general rigidity controller has been superimposed.

The practical experiences and the evaluation of the applied controllers have been performed on a machine test rig with direct drives, for which an experimental control system has been applied.