Case Study: Motor spindle with integrated AVR system

Scope

Each manufacturing process is driven by the demand for high-quality goods at minimum costs. When it comes to production equipment, like milling, turning, drilling or grinding machines, the inevitable vibrations originating from the cutting process are one important factor which could limit the above-mentioned goals. The common approach to counteract chatter vibrations is to adapt the production parameters often resulting in reduced material removal rates.

Approach

From a structural dynamics point of view, the conventional (passive) approach to keep vibration levels low is to build a rigid machine with as much damping as possible. Alternatively, active vibration reduction (AVR) systems can be used. Such systems offer an additional degree of freedom in vibration reduction by actively generating motion or forces with a positive influence on structural dynamics. Depending on the implemented control algorithm, e.g. additional damping or counter-vibrations can be generated resulting in the requested vibration reduction.

Active vibration reduction (AVR) system

Such an AVR system consists of at least a sensor, a controller and an amplifier with actuator. The sensor picks up the vibration of the machine, the controller determines the appropriate counteracting signal, which is amplified and fed to the actuator that induces the counter-vibration into the machine.

![Diagram of AVR system components](image)

Motor spindle with structure-integrated AVR system

In cooperation with Weiss Spindeltechnologie GmbH a prototype of an active motor spindle for high-speed machining had to be developed. A common 80 kW milling spindle served as basis for this development. One of the first steps was to investigate different concepts (actuator types, locations, required forces, etc.) of active systems. This was done by e.g. finite element simulation (see Fig. 2). As a result, piezoceramic stack actuators were integrated into the spindle. The two actuators are arranged in a 90° setup carrying the front bearing unit. By driving the actuators, the front bearing unit can be displaced laterally. A dedicated control algorithm was implemented to increase process limits. Figure 3 shows the results from the prototype commissioning.
Result

With the controller, a stable cutting situation can be achieved. When the controller is switched off, the process immediately becomes unstable and chattering occurs. This effect can be seen from the sensor signals (Figure 3, left) as well as from the surface pictures in Figure 3. For the investigated process parameters an increase in the material removal rate of 50% was achieved by increasing the cutting depth from 4 mm to 6 mm, which was the defined target for this specific project.

Annotation

How far the limits in a milling, turning, drilling or grinding process can be pushed by integrating an AVR in a structure strongly depends on the individual vibration problem (e.g. process, workpiece, material, tool, machine configuration, actuator location). Please contact us for assistance in selecting, engineering and implementing the right AVR system for your application.