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# Adaptive Spindle Damping System with Active Electromagnetic Bearing

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**Abstract**

Advanced machining operation require ultra-high-precision motor spindles, tool chucks and cutting tools, free from tool deflection and vibrations. Available motor spindles and tool chucks generate uncontrolled process deviations at several eigenfrequencies, leading to geometrical and surface distortions. This paper presents a patented design method of a non-typical Adaptive Spindle System with an additional electromagnetic bearing based on mechatronics and adaptive control methods for advanced cutting technologies. In comparison to known active magnetic bearing systems for rotor orientation, a rotor damping is investigated between roller bearings. The static and dynamic performance determination of the AIS motor spindle have been carried out at a speed of up to 15,000 rpm on a test bench with actuator stimulated forces and displacement sensors. The analysis of time-domain and amplitude-frequency characteristics confirmed the demand in adaptive closed-loop control methods compensating tool deflections and vibrations at eigenfrequencies.



*Keywords:* cutting process, motor spindle, damping, electromagentic bearing, adaptive control

## 1. Cutting process demand

A demand for highest precision motor spindles, tool chucks and cutting tools arises for advanced cutting processes, which should be free from tool deflection and vibrations. Dynamically balanced rotors, tool chucks and cutting tools are prerequisites for precision manufacturing.

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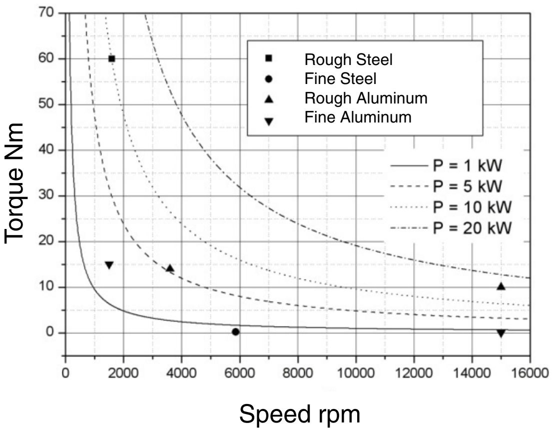



Fig. 1. Cutting process demand

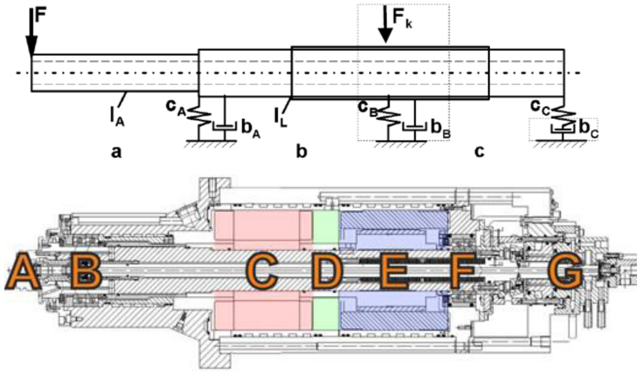
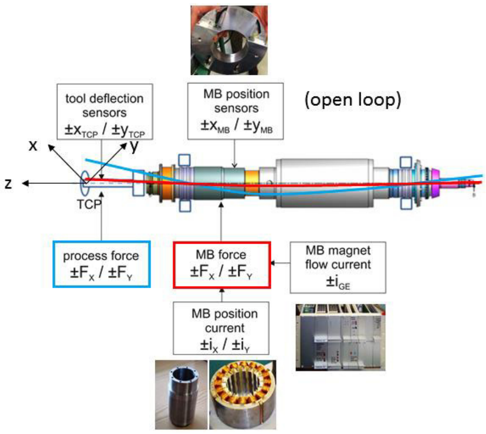



Fig. 2. Motor spindle structure with active EMB

The state of the art analysis in machine tool main spindle units does not include the following adaptive spindle system. [1] Monitoring for cutting process forces and displacements between the tool center point (TCP) and work piece requires additional instrumentation for work piece clamping and spindle. Answering the technological demand (Fig. 1), an innovative Adaptive Spindle System (AS) has been designed with an additional electromagnetic bearing (EMB) for a radial force < 2 kN "C" and EMB position sensors "D" (Fig. 2). Double ball bearings "B" and "F" support the rotor on both sides, while the EMB in the center is shifting the rotor for tool deflection and vibration compensation. [2], [3], [4] The new design model was analyzed for static and dynamic compliance and results in calculated values for stiffness and eigenfrequencies. The experimental performance determination of the AS prototype has been performed on a test bench. (synchronous motor "E" with nominal 82Nm / 4,000 rpm; maximal 34.5kW / 15,000 rpm; water cooling 20°C ±1°C).

## 2. Tool deflection

The deflection of the TCP is a function of the cutting force and electromagnetic bearing force. Experimental tests of the motor spindle with different static TCP/EMB forces result in TCP/EMB displacements, as shown in Figure 3.



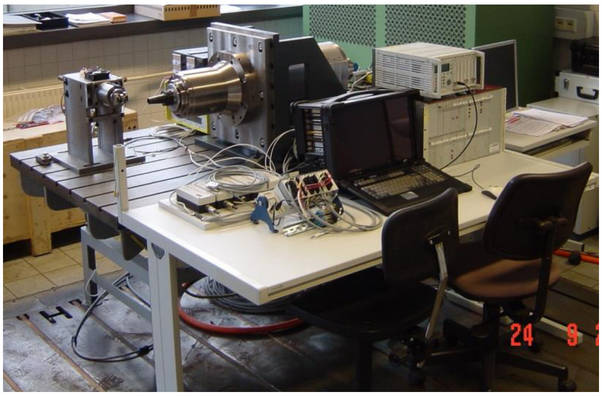



Fig. 3. Experimental test bench a) scheme b) at laboratory