Feedforward and Feedback Control During N-Waved Machining by Magnetic Bearing Spindles

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ABSTRACT

A typical grinding or milling machine has mechanisms for boring of circular orbits. In some cases however, there is a need for machining of non-circular surfaces, for example, surfaces with n-waved cross-sections. Analytical functions, e.g., epicycloids or hypocycloids can describe an n-waved orbit. Such machining can be realized by electro-spindles with active magnetic bearings without any change in the grinding machine mechanism, but by programmed change of the location of spindle shaft in the magnetic bearing planes.

The parametric equations of the desired spindle shaft motion in a tool plane are derived and the optimal motions of the shaft in the magnetic bearing planes are calculated as a desired, from the control point of view, set of operating points. The operating points (trajectory) are a known (i.e., programmed) function of time and angular position.

In the paper we calculate the centrifugal forces from the parameters of the motion on trajectory. They are considered as an external momentum of forces acting on closed loop system (rigid rotor with two radial magnetic bearings) with earlier established pole-placement feedback control. To cancel that momentum we consider the classical approach with counter-forces supplied by a feedforward loop.

Trajectory motion of the non-rotating shaft was investigated in a laboratory stand. Computer simulation results for trajectory motion of rotor rotating in the range 0-120,000 RPM are also presented.

Experiments have shown the influence of the rotor weight, centrifugal force induced by the shaft motion along the trajectory, closed-loop bandwidth, and gain (time constant) in the integration loop on the shape and amplitude of the measured trajectory. Generally, the trajectory without feedforward control is better recorded for slower tool motion along the trajectory, higher gain of integral part, larger load capacity of magnetic bearing, and for wider closed-loop bandwidth.

Experimental investigation of whole system with local feedback and feedforward control confirmed cancellation of centrifugal forces. For rotor parameters which fulfill a condition given in the paper we can design the local (one axis) feedforward control law.