Efficiency of vibration absorber control methods in machining

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(Abstract submitted to Eleventh Conference on Nonlinear Vibrations, Stability, and Dynamics of Structures, August 13-17, 2006, Blacksburg, VA)

Vibrations in common application systems are highly undesirable phenomena and cause many adverse effects. Within machines and civil devices they are responsible for reduction of comfort, an occupational hazard resulting from high vibrations that the user is subject to, a durability decrease and degradation of productivity. In extremely sensitive objects, e.g. bridges, a high level of vibrations leads to structure destruction. Therefore, more and more effective solutions against vibrations are sought for. This can be achieved by using various kinds of passive, semi-active and active absorbers. The main problem connected with the use of passive devices is that vibration suppression can be achieved properly in a very narrow bandwidth of vibration frequency. Present research in passive methods is concentrated on the use of nonlinear components such as nonlinear spring and dashpot, saturation phenomena and nonlinear energy sinks. The aforementioned solutions significantly broaden the effective bandwidth. Semi-active control of vibrations with tuning capability can be achieved by using dampers with variable damping ratios (e.g. magneto- and electrorheological fluid) and springs with variable stiffness (e.g. shape memory alloy). The insertion of external energy by actuators results in full active vibration control. The advantage of this method is its very high flexibility and therefore, the ability to accommodate to a changing environment.

Problems associated with vibrations also appear in machining. A high level of vibrations in the machining process leads to surface quality deterioration. They also cause shortening of the cutting tool life, as well as reduction of machine tool reliability. One of the most important issues concerned with machining are self-excited vibration phenomena, which are depended on cutting parameters and dynamical properties of the machine tool. Several methods to overcome this problem have been applied by various researchers:
1. dynamical properties of the machine tool can be properly shaped at the design stage,
2. regeneration effect control by adaptive changing of spindle speed and/or feed rate,
3. application of vibration absorbers for changing energy flow in machine tool – cutting process system.

The one of the possibilities to reduce the vibration level in machining and improve ultimate cutting process parameters is to apply an electromagnetic, semi-active vibration absorber. A machine tool with such a structure can be treated as a system with two degrees of freedom and that exhibits two natural frequencies. If self-excited vibrations grow in amplitude at the lower frequency, then damping needs to be increased at this bandwidth. Moreover, increasing the value of the upper frequency is desireable. In this way much more energy is necessary to excite the vibration in the vicinity of the second frequency compared with the system where the frequency has not been changed. It allows the reduction of the vibration level to be achieved.

The subject of this work is to compare the effectiveness of various control algorithms for driving semi-active, electromagnetic vibration absorbers incorporated in the machine tool dynamic structure. Two control systems are analyzed in detail: one with suboptimal pole and zero placement and the second one based on the IMP (Internal Model Principle) rule. The fuzzy logic technique and predictive control idea are also considered.

In the first control system the pole and zero location are cross related and cannot be placed independently. Therefore, their locations are optimized by Genetic Algorithm.

The disturbance model is incorporated in the second control system which considers a possibility of developing self-excited vibrations at unknown frequency, unforeseeable from 2-DOF mass-damping-spring (MDS) model. The disturbance model can be adapted to a dominant vibration frequency and allows high efficiency to be preserved. The adaptation is based on the cutting depth signal, which is used as a pseudo-synchronic signal.

The effectiveness of the proposed control system with simulation of a mechanistic model of the cutting process is estimated. Maximal width of cut, at which the vibration level is bounded to a specified range, assist in determining effectiveness of the control algorithm. Additionally the RMS (root mean square) value of the workpiece vibration signal is determined. This is calculated for the period of the cutting edge engagement with the workpiece.

The presented simulation results bring out an improvement in ultimate machining parameters at which vibrostability has been lost. The second method is less sensitive to MDS model accuracy and changing machining parameters.