Abstract

This work reports on methods for identifying arbitrary combinations of friction, backlash and compliance in mechanical drive mechanisms. Friction, backlash and compliance are each presented in sufficient detail to characterise the nonlinearities affecting machine tools in detailed analytical form. The dynamic coupling between the three nonlinear elements is highlighted as being particularly important to improving the precision and accuracy of machine tools and quality of the workpiece product.

A detailed overall analysis is given of dynamic friction, backlash with impact, and multi-modal elastic compliance as they operate interactively in a realistic dynamic environment. It is shown that interaction between these otherwise standard nonlinear elements is a crucial component of successful machine tool controllability. The results are important to the improved mechatronic design of future machine tools as well as the retrofitting of existing tools with better-informed software control. The work has applications to many dynamic systems in general, and especially in the field of robotics. The three basic nonlinearities are examined individually and as components in a complete system. The scheme is first developed analytically, then simulated, and the friction identification methodology is actually tested on two systems mimicking the nonlinearities of a typical machine tool.

Unique contributions include a backlash model with viscoelastic impact properties, and extension of the traditional time-domain identification technique known as the *logarithmic decrement* method to include estimation of asymmetric kinetic and viscous friction for linear, second-order oscillations with time-invariant system parameters. The method may be applied to any such free vibration response, using only the time history of displacement data. Moreover, a novel technique called *parametric harmonic oscillation* is introduced, whereby even highly overdamped systems can be made to mimick underdamped free harmonic vibration, allowing one to apply the extended log decrement method to all second-order systems exhibiting asymmetric kinetic and/or viscous friction. The parametric harmonic oscillation method reveals the actual physical mass, and hence the friction and stiffness parameters of a system, in addition to the usual mass-dimensionalised frequency and damping values. The techniques are demonstrated in theory and simulation, and subsequently verified on two real second-order systems with asymmetric friction. Identification techniques for nonlinear (time-varying) friction and (multimodal) stiffness are also explored.