25 Application of Fieldbus Technology in Mechatronic Systems

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25.1 Introduction

Today’s fiercely competitive market enforced the industries to rapidly deliver quality products to meet the societal demand. Many of the production cells in industry have already been equipped with automated machineries and systems. Out of many machine types, spindle machines are commonly employed in the processes for machining, micromachining, milling, data reading/writing and so on. Employment of high-speed spindle systems (HSSS) is eventually needed in order to demand for increased productivity. Moreover, performance driven state-of-the-art design techniques, methodology and tools must be adopted for building machineries. Potential research and developments in terms of design, modeling and analysis, optimization, performance etc. of rotary machines have been reported since two decades. The study especially on HSSS is rather limited in the sense that a suitable sophisticated design strategy has not been developed so far. The works in this context apparently, concentrate on specific aspects of the rotary systems. For example, Shoda et al studied the performance of the ceramic ball bearings under high-speed condition (Shoda et al. 1997). Others (Jones 1960)-(Shin 1992) have also developed theories and models in the context of studying verities of bearing types and their operational ranges. Harris’s work computes the effects of preload bearing (Harris). Bossmanns derived the thermo-mechanical behavior of the spindles for milling applications (Bossmanns 2001). Boglietti et al, establishes a test procedure for studying the behavior of high-speed drives (Boglietti et al. 1995). Kim and Lee investigated the thermal effects with regard to cylindrical housing of the high-speed rotating machine. Although, Bossmanns described a systematic approach in the context of characterization of flow of power within HSSS through test procedure on special test rigs, however, a real design strategy in terms of mechanical design, multi-domain modeling, control methodology, diagnostics and prognostics, and many other design interfacing requirements including the use of state-of-the-art tools and techniques are missing. As a matter of fact there is a strong needs to investigate the design strategy, since the HSSS are no longer simply the mechanical systems rather, they are mechatronic in nature.
Spindle systems, in their traditional form are composed of a drive, a mechanical structure called housing, bearings (front and back) with preload arrangements, electrical and mechanical interfacings, lubricating and cooling systems. Problems with high-speed spindle system, however, include, issues of tooling, thermal deformation, performance degradation, reliability, electromechanical design concerns (coupling), control strategy, condition monitoring, and balancing. This chapter, without loss of generality of the spindle machineries, advocates some of these issues. Besides studying the behavior of the HSSS, this chapter also exploits a complete design strategy and development processes, which are considered to be paramount important for the manufacturing of a true mechatronic product. The researchers and practitioners can critically evaluate the methods, techniques and ideas used here in. The expanded meaning of design strategy in the context of this chapter (keeping the temporal behavior of the spindle systems intact), includes the following attributes.

- The chapter briefly introduces the conventional spindle machine systems in first place.
- In order to study the characteristics and thus to predict the performance of HSSS, modeling is obviously needed. The model represents the dynamic properties of the spindle. A complete thermo-mechanical modeling approach adhering information about the flow of real power from the input through the output has been presented. It does not ignore the effects of nonlinearity and the losses.
- Since the HSSS must be able to withstand complex dynamic load conditions and be able to operate at a wide speed range with wide range of cutting forces (for machining) a study on thermo-electromechanical behavior must be carried out. This will fulfill the requirements for optimization of design parameters for improved operational performance of the spindling under many circumstances. CAD and sophisticated optimization tools are used for the custom-built design of spindle system for high-speed operation, i.e., above 20,000 RPM.
- The design strategy accommodates Diagnostics and Prognostics (DAP) in terms of FDI (Fault Detection and Isolation) scheme in order to improve the reliability. Various FDI methods and approaches and their relative merits and demerits have been studied. From the review, it was perceived that model-based and spectrum analysis based FDI schemes are suitable for this sorts of machine systems.
- High resolution and precision machines must not tolerate vibration. Since HSSS are susceptible to vibration because of improper coupling, non-uniform shaft density, varying stiffness of the ball bearings and many other factors, advanced anti-vibration technology in terms of balancing methods must be employed. Contrast to traditional balancing methods, this chapter describes an innovative balancing technique. The prototype called EMB (Electro-Magnetic Balancer) has been developed, tested and used in order to reduce the vibration level of the spindle shaft significantly.
- For the first time, a metaphoric idea in terms of SEA (Sustainability and Evolution Assessment) has been implemented so as to provide a knowledge base to