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Identification of a machine tool spindle critical frequency through modal and imbalance response analysis

Jauhari, Khairul ; Widodo, Achmad; Haryanto, Ismoyo

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[a] Department of Mechanical Engineering, University of Diponegoro, Semarang, Indonesia

Abstract

The most important part for machine tool system is spindle system. The structural properties of spindle will affect to the productivity of machining process and the work pieces quality. Thus it is necessary and very important to know its spindle dynamic behaviors for avoiding forced vibration due to resonance. The Finite Element Method (FEM) has been adopted for obtaining spindle dynamic behaviors. FEM model and analysis of dynamic behaviors for the spindle system are similar to those developed in rotor-dynamic. The main purpose of this study, we implemented an ANSYS Parametric Design Language (APDL) program based on finite element method for obtaining full analysis of rotor dynamic in order to investigate the spindle dynamic behaviors. The programs efficiently performed the full analysis by determining the Campbell diagrams, critical speeds and response of imbalance due to mass unbalance at the cutting tool. Results show that the critical speeds were calculated previously are far enough from the spindle speeds operating range, then the spindle would not experience resonance and the maximum response of imbalance occurs on operating speed is also in acceptable limit. ANSYS

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American Journal of Engineering and Applied Sciences

Original Research Paper

Identification of a Machine Tool Spindle Critical Frequency through Modal and Imbalance Response Analysis

Khairul Jauhari, Achmad Widodo and Ismoyo Haryanto

Department of Mechanical Engineering, University of Diponegoro, Semarang, Indonesia

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Corresponding Author:
Khairul Jauhari,
Department of Mechanical Engineering, University of Diponegoro, Semarang, Indonesia
Email: khairul.j4uhari@gmail.com

Abstract: The most important part for machine tool system is spindle system. The structural properties of spindle will affect to the productivity of machining process and the work pieces quality. Thus it is necessary and very important to know its spindle dynamic behaviors for avoiding forced vibration due to resonance. The Finite Element Method (FEM) has been adopted for obtaining spindle dynamic behaviors. FEM model and analysis of dynamic behaviors for the spindle system are similar to those developed in rotor-dynamic. The main purpose of this study, we implemented an ANSYS Parametric Design Language (APDL) program based on finite element method for obtaining full analysis of rotor dynamic in order to investigate the spindle dynamic behaviors. The programs efficiently performed the full analysis by determining the Campbell diagrams, critical speeds and response of imbalance due to mass unbalance at the cutting tool. Results show that the critical speeds were calculated previously are far enough from the spindle speeds operating range, then the spindle would not experience resonance and the maximum response of imbalance occurs on operating speed is also in acceptable limit. ANSYS Parametric Design Language (APDL) can be used by spindle designer as tools in order to increase the product quality, reducing cost and time consuming in the design and development stages.

Keywords: ANSYS Parametric Design Language (APDL), Campbell Diagram, Critical Speeds, Imbalance Response, Spindle System

Introduction

The most important components for machine tool system is the system of spindle. The dynamic properties of spindle directly affect to the machining productivity and quality of the product. In the design and development stages, then it is very necessary and important to know the behaviors of spindle dynamics for avoiding resonance of critical speeds due to machining operations. To obtain dynamic analysis of spindle system analytically in the early design stage, the Finite Element Method (FEM) has been frequently adopted for modeling of spindle dynamic behaviors. Basically, the FEM model and dynamic analysis for the spindle systems of machine tools is similiar to those developed in rotordynamic. However, the spindle shafts used in machine tools usually have smaller shaft diameters and bearings and possess disk-like in turbomachine components. Thus in this study, we attempt to review some researches relating to the field of rotordynamics.

Lin *et al*. (2013) in their paper stated that the most popular approch for modeling the spindle dynamic behavior is the Finite Element Model (FEM), because of its capability to manage complex geometry and boundary condition and the calculation approaches save time and money while solving the finite element system equation. Lin (2014) developed a Genetic Algorithm (GA) optimization approach to search the optimal location of bearings on the motorized spindle shaft. The goal is to maximize its First-Mode Natural Frequency (FMNF). In order to achieve the results, a spindle-bearing system dynamic model is formulated using Finite Element Method (FEM) that was developed in the rotordynamics. Nelson and McVaugh (1976; Nelson, 1980) applied the theory of Timoshenko's beam to build matrix of systems in order to analyze the rotor systems dynamics including the influences of gyroscopic moments, rotational inertia, axial load and shear deformation. Zorzi and Nelson (1977) presented the influences of damping on the rotating systems dynamics.

American Journal of Engineering and Applied Sciences

Original Research Paper

Fragment-based Visual Tracking with Multiple Representations

[1]Junqiu Wang and [2]Yasushi Yagi

[1]*AVIC Intelligent Measurement, Aviation Industry Cooperation China, Beijing, China*
[2]*The Institute of Scientific and Industrial Research, Osaka University, Osaka, Japan*

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Corresponding Author:
Junqiu Wang
AVIC Intelligent Measurement,
Aviation Industry Cooperation
China, Beijing, China
Email: jerywangjq@gmail.com

Abstract: We present a fragment-based tracking algorithm that considers appearance information characterized by a non-parametric distribution and spatial information described by a parametric representation. We segment an input object into several fragments based on the appearance similarity and spatial distribution. Spatial distribution and appearance are important for distinguishing different fragments. We employee such information for separating an object from its background: Appearance information is described by nonparametric representation such as kernels; spatial information is characterized by Gaussians with spatial distribution of fragments. We integrate appearance and spatial information for target localization in images. The overall motion is estimated by the mean shift algorithm. This motion can deviate from the true position in the overall motion estimation because of the mean-shift drifting. We refine the estimated position based on the foreground probabilities. The proposed tracker gives better target localization results and better foreground probability images. Our experimental results demonstrate that the integration of appearance and spatial information by combining parametric and non-parametric representation is effective for tracking targets in difficult sequences.

Keywords: Visual Tracking, Fragment-Based Tracking, Parametric and Non-Parametric Representation, Appearance and Spatial Information

Introduction

Visual tracking is still a hard problem after the intensive investigation over the years. Adaptive tracking (Collins *et al*., 2005; Han and Davis, 2004; Wang and Yagi, 2013) is effective for improving the tracking accuracy of a tracking algorithm by choosing good features that distinguish the object against its background. Unfortunately, model drifts bring difficulties for adaptive tracking (Jepson *et al*., 2003; Collins *et al*., 2005). To make the target model adaptive to the appearance variations, the tracker has to classify the pixels in the region into foreground and background. The classification process can mistakenly classified background pixels as foreground. Such pixels are incorporated into the object model. Thus the model updating makes the object representation drift from the true representation. The misclassification of the pixels can lead to the failure of the trackers for adaptive model updating. This problem can be partially solved by using an effective representation of targets and their background. The objective of this work is to improve the pixel classification by explicitly considering spatial distribution and appearance representation. We also investigate on how to use effective representation in the localization process for a visual tracker.

Different trackers try to find good target and background description approaches and target localization methods. Object characterization and position estimation are the two important issues that need to be addressed in developing an effective tracker. A good object representation can describe the essence of the object that is representative for the object and sufficiently discriminative for distinguishing the object from the background. Moreover, the characterization needs adaptive ability for handling object changes due to illumination variations or viewpoints changes.

Histograms are simple and effective nonparametric representations. Other nonparametric forms such as kernel density estimation are proposed for better performance. A target can be described by a kernel

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Original Research Paper

On the General Solution of First-Kind Hypersingular Integral Equations

[1]Suzan J. Obaiys, [1]Z. Abbas, [2]N.M.A. Nik Long, [2]A.F. Ahmad, [2]A. Ahmedov and [3]Haider Khaleel Raad

[1]*Department of Physics, Universiti Putra Malaysia, Serdang, Malaysia*
[2]*Institute for Mathematical Research, Universiti Putra Malaysia, Serdang, Malaysia*
[3]*Department of Physics, Xavier University, Cincinnati, Ohio, USA*

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Corresponding Author:
Suzan J. Obaiys
Department of Physics, Universiti Putra Malaysia, Serdang, Malaysia
Email: suzan_ye@yahoo.com

Abstract: A new algorithm is presented to provide a general solution for a first type Hyper singular Integral Equation (HSIE). The singular integral has been converted into a regular form by cancelling the singularity and then transforming it into a system of algebraic equation based orthogonal polynomials. We applied the convergence method presented by (Obaiys, 2013) to conform the numerical solution of the regularized Hadamard equation, which has shown an absolute agreement with the exact solution within small values of *n*. The proposed method has been examined by various HSIEs where the displacement function satisfies the Hölder-continuous first derivative. Such equations are particularly important inmany physics and engineering problems, such as fracture mechanics, acoustics and elasticity.

Keywords: HSIE, Singular Integrals, Fredholm Integral Equation, Chebyshev Polynomials

Introduction

Basic Concepts

One of the most frequently used numerical applications is the integral equation methods due to their ability to resolve the strong singularities that arise in stress fields where the boundary conditions change type (Lifanov *et al*., 2003; Iovane *et al*., 2003; Obaiys *et al*., 2012a). We present a new general solution for the first type HSIEs, whereas this approach depends on the analytical evaluation of the singular integral after the reduction for the higher order singularity. Integral equations arise in many physical problems, such as elasticity, acoustics and fracture mechanics which require the analytical solution of Fredholm integral equation (Martin and Rizzo, 1989; Martin, 1992; Obaiys *et al*., 2013):

$$\int_L \lambda(t,x)g(t)dt = f(x), \quad x \in L \tag{1}$$

where, λ is a square integrable kernel of (*t, x*) that has a logarithmic singularity on the diagonal $t = x$:

$$\int_L\int_L \lambda^2(t,x)dtdx = B^2 < \infty \tag{2}$$

If *L* is a piecewise smooth contour that includes the interval [-1,1], (i.e.: Here we deal with an equation with Hilbert kernel). The regular part of the kernel λ can be separated as singular and nonsingular parts by using the decomposing Fourier transform. Thus, by considering the segment [-1,1]as a special case of *L*, Equation 1 becomes:

$$\frac{1}{\pi}\int_{-1}^{1} K(t,x)g(t)dt + \int_{-1}^{1} G(t,x)g(t)dt = f(x), \quad x \in [-1,1] \tag{3}$$

where, $G(t,x)$ is a regular kernel of *t* and *x* while the first kernel $K(t,x)$ has the form:

$$K(t,x) = \frac{h(x)}{(t-x)^{\alpha}}, \quad \alpha \ge 2 \tag{4}$$

Which is called the hyper singular kernel and $K(x,x) \ne 0$ and $h(t)$ is unknown function to be determined.

Furthermore α is the order of the integral which classifies its singularity. If α = 2, then Equation 3 becomes: