Mann, Brian P.; **Young, Keith A.**

An empirical approach for delayed oscillator stability and parametric identification. (English)
Zbl 1149.70323

Proc. R. Soc. Lond., Ser. A, Math. Phys. Eng. Sci. 462, No. 2071, 2145-2160 (2006).

Summary: This paper investigates a semi-empirical approach for determining the stability of systems that can be modelled by ordinary differential equations with a time delay. This type of model is relevant to biological oscillators, machining processes, feedback control systems and models for wave propagation and reflection, where the motion of the waves themselves is considered to be outside the system model. A primary aim is to investigate the extension of empirical Floquet theory to experimental or numerical data obtained from time-delayed oscillators. More specifically, the reconstructed time series from a numerical example and an experimental milling system are examined to obtain a finite number of characteristic multipliers from the reduced order dynamics. A secondary goal of this work is to demonstrate a benefit of empirical characteristic multiplier estimation by performing system identification on a delayed oscillator. The principal results from this study are the accurate estimation of delayed oscillator characteristic multipliers and the utilization the empirical results for parametric identification of model parameters. Combining these results with previous research on an experimental milling system provides a particularly relevant result – the first approach for identifying all model parameters for stability prediction directly from the cutting process vibration history.

MSC:

70K20 Stability for nonlinear problems in mechanics
93B30 System identification

Keywords:

time delay; empirical Floquet theory; milling

Full Text: DOI

References:

[1] Abarbanel, H. 1996 <i>Analysis of observed chaotic data</i>, USA: Springer

[2] Altintas, Y. & Budak, E. 1995 Analytical prediction of stability lobes in milling. <i>CIRP Ann.</i> 44, 357–362.

[3] Baker, C.T., Bocharov, G.A., Paul, C.A. & Rihan, F.A. 1998 Modelling and analysis of time-lags in some basic patters of cell proliferation. <i>J. Math. Biol.</i> 37, 341–371, (doi:10.1007/s002850050133). · Zbl 0908.92026

[4] Balachandran, B. 2001 Non-linear dynamics of milling process. <i>Proc. R. Soc. A</i> 359, 793–819. · Zbl 1056.74026

[5] Bayly, P.V. & Virgin, L.N. 1993 An empirical study of the stability of periodic motion in the forced spring-pendulum. <i>Proc. R. Soc. A</i> 443, 391–408. · Zbl 0822.70015

[6] Bayly, P.V., Halley, J.E., Davies, M.A. & Mann, B.P. 2003 Stability of interrupted cutting by time finite element analysis. <i>J. Manuf. Sci. Eng.</i> 125, 220–225, (doi:10.1115/1.1556860).

[7] Chatterjee, A. 2000 An introduction to the proper orthogonal decomposition. <i>Curr. Sci.</i> 78, 808–817.

[8] Davies, M.A., Pratt, J.R., Dutterer, B. & Burns, T.J. 2002 Stability prediction for low radial immersion milling. <i>J. Manuf. Sci. Eng.</i> 124, 217–225, (doi:10.1115/1.1455030).

[9] Guckenheimer, J. & Holmes, P.J. 1983 <i>Nonlinear oscillations, dynamical systems, and bifurcations of vector fields</i>, ch. 1. pp. 12–33, New York: Springer · Zbl 0515.34001

[10] Hale, J.K. & Verduyn, L.S. 1993 Introduction to functional differential equations. New York: Springer. · Zbl 0787.34002

[11] Insperger, T. & Stépán, G. 2002 Stability chart for the delayed mathieu equation. <i>Proc. R. Soc. A</i> 458, 1989–1998, (doi:10.1098/rspa.2001.0941). · Zbl 1056.34073

[12] Insperger, T., Mann, B.P., Stépán, G. & Bayly, P.V. 2003 Stability of up-milling and down-milling, part 1: alternative analytical methods. <i>Int. J. Mach. Tool. Manuf.</i> 43, 25–34, (doi:10.1016/S0890-6955(02)00159-1).

[13] Insperger, T., Stépán, G., Bayly, P.V. & Mann, B.P. 2003 Multiple chatter frequencies in milling processes. <i>J. Sound Vib.</i> 262, 333–345, (doi:10.1016/S0022-460X(02)01131-8).

[14] Kantz, H. & Schreiber, T. 2004 <i>Nonlinear time series analysis</i>, 2nd edn. Cambridge, UK: Cambridge University Press · Zbl 1050.62093

[15] Mann, B.P., Insperger, T., Bayly, P.V. & Stépán, G. 2003 Stability of up-milling and down-milling, part 2: experimental verification. <i>Int. J. Mach. Tool. Manuf.</i> 43, 35–40, (doi:10.1016/S0890-6955(02)00160-8).

[16] Mann, B.P., Bayly, P.V., Davies, M.A. & Halley, J.E. 2004 Limit cycles, bifurcations, and accuracy of the milling process. <i>J. Sound Vib.</i> 277, 31–48, (doi:10.1016/j.jsv.2003.08.040).

[17] Mann, B.P., Young, K.A., Schmitz, T.L. & Dilley, D.N. 2005 Simultaneous stability and surface location error prediction in milling. <i>J. Manuf. Sci. Eng.</i> 127, 446–453, (doi:10.1115/1.1948394).

[18] Mann, B.P., Garg, N., Young, K.A. & Helvey, A.M. 2005 Milling bifurcations from structural asymmetry and nonlinear regeneration. <i>Nonlin. Dyn.</i> 42, 319–337, (doi:10.1007/s11071-005-5719-y). · Zbl 1142.70327

[19] Nayfeh, A.H. & Balachandran, B. 1995 <i>Appl. Nonlin. Dyn.</i>, New York: Wiley

[20] Olgac, N. & Sipahi, R. 2005 A unique methodology for chatter stability mapping in simultaneous machining. <i>J. Manuf. Sci. Eng.</i> 127, 791–800.

[21] Peters, D.A. & Idzapanah, A.P. 1988 Hp-version finite elements for the space-time domain. <i>Comput. Mech.</i> 3, 73–78, (doi:10.1007/BF00317056).

[22] Sinha, S.C., Pandiyan, R. & Bibb, J.S. 1996 Liapunov-Floquet transformation: computation and applications to periodic systems. <i>J. Vib. Acoust.</i> 118, 209–219.

[23] Stépán, G. 1989 <i>Retarded dynamical systems</i>, New York: Longman

[24] Stépán, G. 2001 Nonlinear regenerative effect in metal cutting. <i>Proc. R. Soc. A</i> 359, 739–757. · Zbl 1169.74431

[25] Tlusty, J. 2000 <i>Manufacturing processes and equipment</i>, Upper Saddle River: Prentice Hall

[26] Virgin, L.N. 2000 <i>Introduction to experimental nonlinear dynamics</i>, Cambridge, UK: Cambridge University Press

[27] Wahi, P. & Chatterjee, A. 2004 Averaging oscillations with small fractional damping and delayed terms. <i>Nonlin. Dyn.</i> 38, 3–22, (doi:10.1007/s11071-004-3744-x). · Zbl 1142.34385