



土结构动力相互作用的实时耦联动力试验的时滞稳定性

迟福东, 王进廷, 金峰, 徐艳杰

清华大学水沙科学与水利水电工程国家重点实验室, 北京 100084

DELAY-DEPENDENT STABILITY OF REAL-TIME DYNAMIC HYBRID TESTING FOR SOIL-STRUCTURE INTERACTION ANALYSIS

CHI Fu-dong, WANG Jin-ting, JIN Feng, XU Yan-jie

State Key Laboratory of Hydrosience and Hydraulic Engineering, Tsinghua University, Beijing 100084, China

- [摘要](#)
- [图/表](#)
- [参考文献](#)
- [相关文章](#)

全文: [PDF \(729 KB\)](#) [HTML \(1 KB\)](#) 输出: [BibTeX](#) | [EndNote \(RIS\)](#) [背景资料](#)

摘要

针对土-结构动力相互作用的实时耦联动力试验(SSI-RTDHT),以单自由度上部结构体系为例,建立了考虑振动台时滞及其补偿的数学模型;然后采用基于Padé展开逼近时滞项的根轨迹方法研究其稳定性;最后利用数值仿真验证了理论分析得出的稳定条件.研究表明:时滞明显地改变了系统固有模态的动力特性,并使得SSI-RTDHT成为一个条件稳定系统;稳定性随时滞和上部结构频率的增大而降低,随地基特征频率的增大而提高;上部结构阻尼比对稳定性影响不大.三阶多项式补偿会明显降低试验体系的稳定性,但可以改善固有模态的性能.

关键词: [结构试验技术](#) [实时耦联动力试验](#) [土-结构动力相互作用](#) [时滞](#) [稳定性](#) [根轨迹方法](#)

Abstract:

Taking a single degree-of-freedom structural system as an example, the mathematical model of real-time dynamic hybrid testing for soil-structure interaction analysis (SSI-RTDHT) is established, where shaking table response delay and delay compensation strategy are included. Then the stability of the time-delayed system is investigated using the root locus technique based on Padé decomposition approximating the delay term. Finally, some numerical experiments are performed to validate the obtained stability conditions. The results show that the performance of the inherent mode is changed and SSI-RTDHT becomes conditionally stable due to the delay; the stability is worsen with increasing of the delay and the natural frequency of upper structure, and it is improved with increasing of the characteristic frequency of the foundation; the influence of the damping ratio of the upper structure on the stability is relatively small. The results also show that third-order polynomial compensation will make the stability worse, but it can improve the performance of the inherent mode.

Key words: [seismic testing](#) [real-time dynamic hybrid testing](#) [dynamic soil-structure interaction](#) [delay](#) [stability](#) [root locus technique](#)

收稿日期: 2010-11-03; 出版日期: 2012-05-23

PACS: [TU317](#)

[O327](#)

基金资助:

国家自然科学基金项目(40974063,50779021,90715041);水沙科学与水利水电工程国家重点实验室自主研究课题项目(2008-TC-2)

通讯作者: 金峰(1966-),男,贵州人,教授,博士,博导,从事水工结构及防震减灾方面的科研与教学工作(E-mail:

jinfeng@tsinghua.edu.cn). E-mail: jinfeng@tsinghua.edu.cn

服务

- ▶ [把本文推荐给朋友](#)
- ▶ [加入我的书架](#)
- ▶ [加入引用管理器](#)
- ▶ [E-mail Alert](#)
- ▶ [RSS](#)

作者相关文章

- ▶ [迟福东](#)
- ▶ [王进廷](#)
- ▶ [金峰](#)
- ▶ [徐艳杰](#)

作者简介: 迟福东(1982—),男,云南人,博士生,从事结构动力试验方面的科研工作(E-mail: chifudong@gmail.com);
王进廷(1973—),男,山西人,副教授,博士,从事结构抗震及动力试验方面的科研与教学工作(E-mail: wangjt@tsinghua.edu.cn);
徐艳杰(1970—),女(满),辽宁人,副教授,博士,从事水工结构及防震减灾方面的科研与教学工作(E-mail:
xuyanjie@tsinghua.edu.cn).

引用本文:

迟福东,王进廷,金峰等. 土结构动力相互作用的实时耦联动力试验的时滞稳定性[J]. 工程力学, 2012, 29(8): 1-7.

CHI Fu-dong,WANG Jin-ting,JIN Feng et al. DELAY-DEPENDENT STABILITY OF REAL-TIME DYNAMIC HYBRID TESTING FOR SOIL-STRUCTURE INTERACTION ANALYSIS[J]. Engineering Mechanics, 2012, 29(8): 1-7.

链接本文:

<http://gclx.tsinghua.edu.cn/CN/10.6052/j.issn.1000-4750.2010.11.0798>

没有找到本文相关图表信息

[1]

[1] Nakashima M, Takaoka H K E. Development of real-time pseudo dynamic testing [J]. Earthquake Engineering & Structural Dynamics, 1992, 21(1): 79-92.



[2]



[3]

[2] Horiuchi T, Nakagawa M. Development of a real-time hybrid experimental system with actuator delay compensation [C]. 11th World Conference on Earthquake Engineering, 1996.

[4]

[3] 王倩颖, 吴斌, 欧进萍. 考虑作动器时滞及其补偿的实时子结构实验稳定性分析[J]. 工程力学, 2007, 24(2): 9-14, 8. Wang Qianying, Wu Bin, Ou Jinping. Stability analysis of real-time substructure testing considering actuator delay and compensation [J]. Engineering Mechanics, 2007, 24(2): 9-14, 8. (in Chinese)



[5]

[4] 汪强, 王进廷, 金峰, 张楚汉. 结构-地基动力相互作用的实时耦联动力试验[J]. 工程力学, 2011, 28(2): 94-100, 185. Wang Qiang, Wang Jinting, Jin Feng, Zhang Chuhan. Soil-structure interaction analysis by real-time dynamic hybrid testing [J]. Engineering Mechanics, 2011, 28(2): 94-100, 185. (in Chinese) 浏览

[6]

[5] 迟福东, 王进廷, 金峰, 汪强. 土-结构-流体动力相互作用的实时耦联动力试验[J]. 岩土力学, 2010, 31(12): 3765-3770. Chi Fudong, Wang Jinting, Jin Feng, Wang Qiang. Real-time dynamic hybrid testing for soil-structure-fluid interaction analysis [J]. Rock and Soil Mechanics, 2010, 31(12): 3765-3770. (in Chinese)

[7]

[6] Wallace M I, Sieber J, Neild S A, Wagg D J, Krauskopf B. Stability analysis of real-time dynamics substructuring using delay differential equation models [J]. Earthquake Engineering & Structural Dynamics, 2005, 34(15): 1817-1832.

[8]



[9]

[7] Chen C, Ricles J M. Stability analysis of SDOF real-time hybrid testing systems with explicit integrational algorithms and actuator delay [J]. Earthquake Engineering & Structural Dynamics, 2008, 37(4): 597-613.

[10]



[11]

[8] Mercan O, Ricles J M. Stability analysis for real-time pseudodynamic and hybrid pseudodynamic testing with multiple sources of delay [J]. Earthquake Engineering & Structural Dynamics, 2008, 37(10): 1269-1293.



[12]



[13]

[9] 迟福东, 王进廷, 金峰. 实时耦联动力试验的时滞稳定性分析[J]. 工程力学, 2010, 27(9): 12-16, 54. Chi Fudong, Wang Jinting, Jin Feng. Delay-dependent stability analysis of real-time dynamic hybrid testing [J]. Engineering Mechanics, 2010, 27(9): 12-16, 54. (in Chinese) 浏览

[14]

- [10] 迟福东, 王进廷, 汪强, 金峰. 考虑补偿的多自由度实时耦联动力试验时滞稳定性分析[J]. 工程力学, 2011,28(4): 200-207. Chi Fudong, Wang Jinting, Wang Qiang, Jin Feng. Delay-dependent stability analysis of MDOF real-timedynamic hybrid testing considering compensation [J]. Engineering Mechanics, 2011, 28(4): 200-207. (inChinese) 浏览
- [15]
- [11] 栾茂田, 林皋. 地基动力阻抗的双自由度集总参数模型[J]. 大连理工大学学报, 1996, 36(4): 477-482. Luan Maotian, Lin Gao. 2-DOF lumped-parameter model of dynamic impedances of foundation soils [J]. Journal of Dalian University of Technology, 1996, 36(4): 477-482. (in Chinese) 
- [16]
- [12] 罗专翼, 程桂芬, 付家才. 控制工程与信号处理[M]. 北京: 化学工业出版社, 2004. Luo Zhuanyi, Cheng Guifen, Fu Jiakai. Control Engineering and Signal Processing [M]. Beijing: Chemical Industry Press, 2004. (in Chinese)
- [17]
- [13] The Mathworks, Inc. Matlab Software: User' s Guides(2006b) [M]. Natick MA US: The Mathworks, Inc, 2006. 
- [1] 蔡建国, 涂展麒, 冯健, 张晋. 初始缺陷对三向张弦梁结构整体稳定性影响研究[J]. 工程力学, 2012, 29(8): 220-226.
- [2] 马少俊, 胡安峰, 王奎华. 地震作用下挡土墙的滑动稳定性分析[J]. 工程力学, 2012, 29(7): 209-213.
- [3] 石姗姗; 孙直; 任明法; 陈浩然. 格栅非均匀分布效应对复合材料格栅加筋圆锥壳体稳定性的影响[J]. , 2012, 29(4): 43-48.
- [4] 安子军; 张鹏; 杨作梅. 摆线钢球行星传动系统参数振动特性研究[J]. , 2012, 29(3): 244-251.
- [5] 翁赞, 童根树. 非等高双重抗侧力体系的稳定性[J]. 工程力学, 2012, 29(10): 162-169, 176.
- [6] 马文勇; 顾明. 考虑摆动效应的覆冰导线两自由度驰振稳定性分析[J]. , 2012, 29(1): 195-201.
- [7] 杜进生; 康景亮; 罗小峰. 考虑施工缺陷和初始偏心的高墩稳定性分析[J]. , 2011, 28(增刊I): 115-118, .
- [8] 孟晓亮; 郭震山; 丁泉顺; 朱乐东; . 风嘴角度对封闭和半封闭箱梁涡振及颤振性能的影响[J]. , 2011, 28(增刊I): 184-188, .
- [9] 徐龙河; 李忠献; 钱稼茹. 半主动预测控制系统的时滞与补偿[J]. , 2011, 28(9): 79-083.
- [10] 崔杰; 焦永树; 曹维勇; 蔡宗熙. 各向异性地层中井孔周围应力场的研究[J]. , 2011, 28(7): 31-036.
- [11] 郭彦林; 王永海. 两层通高区群柱面外稳定性能与设计方法研究[J]. , 2011, 28(6): 52-059.
- [12] 杨玫; 王丽丽; 张树道. Rayleigh-Taylor不稳定性诱导湍流混合的数值模拟[J]. , 2011, 28(6): 236-241.
- [13] 王永海; 郭彦林. 十字型刚架中轴压柱面外稳定性设计方法研究[J]. , 2011, 28(5): 54-063.
- [14] 文颖; 曾庆元. 平稳运动稳定性分析的位移变分法[J]. , 2011, 28(4): 1-006, .
- [15] 迟福东; 王进廷; 汪强; 金峰; . 考虑补偿的多自由度实时耦联动力试验时滞稳定性分析[J]. , 2011, 28(4): 200-207.

Copyright © 2012 工程力学 All Rights Reserved.

地址: 北京清华大学新水利馆114室 邮政编码: 100084

电话: (010)62788648 传真: (010)62788648 电子信箱: gclxbjb@tsinghua.edu.cn

本系统由北京玛格泰克科技发展有限公司设计开发 技术支持: support@magtech.com.cn