Advances in Aircraft and Spacecraft Science, *Vol. 9, No. 6 (2022) 553-569*
https://doi.org/10.12989/aas.2022.9.6.553

Aircraft and spacecraft structural analysis with hybrid criterion of smart control

C.C. Hung*[1,2] and T. Nguyễn[3]

[1]*Department of Mechanical Engineering, National Taiwan University, Taiwan*
[2]*Faculty of National Hsin Hua Senior High School, Tainan, Taiwan*
[3]*Ha Tinh University, Dai Nai Campus, No. 447, Street 26/3, Dai Nai Ward, Ha Tinh City, Vietnam*

(Received April 22, 2022, Revised August 8, 2022, Accepted December 1, 2022)

Abstract. In this article, we propose a criterion for ensuring the asymptotic stability of large multiple delays, based on the direct Lyapunov method. Based on this criterion and distributed control scheme, the controllers are synthesized by the PDC to stabilize these large-scale systems with multiple delays. And we focus on the results which shows the high effective by the proposed theory utilized for damage propagation for aircraft structural analysis of composite materials. Finally, the numerical simulations confirmed the effectiveness of the method.

Keywords: aerospace vehicles; LMI; nonlinear systems; smart control; stability analysis

1. Introduction

Mathematics seems to be a guide, appearing by the physicist at the right time, bringing light to the gloomy world of physics. However, the mutual influence of mathematics and physics is far more complicated than the story told. In most recorded history, physics and mathematics are not even separate subjects. The mathematics of ancient Greece, Egypt, and Babylon believed that we live in a world where distance, time, and gravity all operate in a certain way. The mathematical and statistical models for many physical, nature and technical systems are generally large or contain dynamic interaction phenomena and the cost for testing these models of control purposes are often too high. Therefore, it is natural to find a technique that can reduce the calculation costs. The large systems methodology provides this technique by manipulating the structure of the system in some way. Therefore, research on modeling, math, analysis, collection, optimization and control of large-scale systems has generated great interest. Recently, many of these methods have been proposed to verify the stability of the literature and the stability of large systems (Yang and Chang 1996, Bedirhanoglu 2014, 2004, 2005, Chiang *et al.* 2007, Liu *et al.* 2009, Liu *et al.* 2010, Hung *et al.* 2019, Eswaran and Reddy 2016 and references included).

In a computer network, because different communication subnets and network architectures adopt different transfer control methods, the transfer delay in the communication subnet is determined by the network status. The delay time caused by the electrical signal response is fixed. The smaller the response time, the smaller the delay, the larger the bandwidth, and the higher the

*Corresponding author, E-mail: zykj_zywd@163.com

http://www.techno-press.org/?journal=aas&subpage=7 ISSN: 2287-528X (Print), 2287-5271 (Online)

$$\le -\sum_{j=1}^{J}\left\{[\sum_{i=1}^{r_j} h_{ij}^2(t)\lambda_m(Q_{ij}) + \sum_{i<f}^{r_j} h_{ij}(t)h_{fj}(t)\lambda_m(Q_{ifj})]\left\|x_j(t)\right\|^2 - \bar{\lambda}_j\sum_{k=1}^{N_j}\left\|x_j(t-\tau_{kj})\right\|^2\right\} \quad \text{(A.7)}$$

According to these Eq. (3.4), we therefore get $\dot{V} < 0$ as well as the proof in condition (I) is then satisfied.

(II): Based in Eq. (A.7), we then get

$$\dot{V} \le -\sum_{j=1}^{J}\left\{[\sum_{i=1}^{r_j} h_{ij}^2(t)\lambda_m(Q_{ij}) + \sum_{i<f}^{r_j} h_{ij}(t)h_{fj}(t)\lambda_m(Q_{ifj})]\left\|x_j(t)\right\|^2 - \bar{\lambda}_j\sum_{k=1}^{N_j}\left\|x_j(t-\tau_{kj})\right\|^2\right\}$$

$$= -\sum_{j=1}^{J}\{\begin{bmatrix}\sqrt{\sum_{k=1}^{N_j}\left\|x_j(t-\tau_{kj})\right\|^2} & h_{1j}(t)\left\|x_j(t)\right\| & h_{2j}(t)\left\|x_j(t)\right\| & \cdots & h_{r_j j}(t)\left\|x_j(t)\right\|\end{bmatrix}$$

$$\cdot\begin{bmatrix}-\bar{\lambda}_j & 0 & 0 & \cdots & 0\\ 0 & \lambda_{1j} & 1/2\lambda_{12j} & \cdots & 1/2\lambda_{1r_j j}\\ 0 & 1/2\lambda_{12j} & \lambda_{2j} & \cdots & 1/2\lambda_{2r_j j}\\ \vdots & \vdots & \vdots & \vdots & \vdots\\ 0 & 1/2\lambda_{1r_j j} & 1/2\lambda_{2r_j j} & \cdots & \lambda_{r_j j}\end{bmatrix}\cdot\begin{bmatrix}\sqrt{\sum_{k=1}^{N_j}\left\|x_j(t-\tau_{kj})\right\|^2}\\ h_{1j}(t)\left\|x_j(t)\right\|\\ h_{2j}(t)\left\|x_j(t)\right\|\\ \vdots\\ h_{r_j j}(t)\left\|x_j(t)\right\|\end{bmatrix}\}$$

$$= -\sum_{j=1}^{J} H_j^T \Lambda_j H_j ,$$

in which $H_j^T \equiv \begin{bmatrix}\sqrt{\sum_{k=1}^{N_j}\left\|x_j(t-\tau_{kj})\right\|^2} & h_{1j}(t)\left\|x_j(t)\right\| & h_{2j}(t)\left\|x_j(t)\right\| & \cdots & h_{r_j j}(t)\left\|x_j(t)\right\|\end{bmatrix}$. The Lyapunov math derivatives are negative if one of these matrices Λ_j ($j = 1, 2, \cdots, J$) is positive digit, which accomplish one of the proof in condition (II).