Available online at www.sciencedirect.com

SciVerse ScienceDirect

Journal of the Franklin Institute 350 (2013) 1189–1205

Journal of The Franklin Institute

www.elsevier.com/locate/jfranklin

Dissipative performance control with output regulation for continuous-time descriptor systems

Yu Feng[a,b,*], Mohamed Yagoubi[c], Philippe Chevrel[c]

[a]Department of Information Engineering, Zhejiang University of Technology, 288 Liuhe Road, Hangzhou, 310032 Zhejiang, PR China

[b]Department of Electrical and Computer Engineering, University of Windsor, 401 Sunset Avenue, Windsor, Ontario, Canada, N9B 3P4

[c]LUNAM Université, Ecole des Mines de Nantes, IRCCyN UMR CNRS 6597 (Institut de Recherche en Communications et Cybernétique de Nantes), 4, rue Alfred Kastler, 44307 Nantes, France

Received 30 July 2012; received in revised form 16 February 2013; accepted 23 February 2013
Available online 7 March 2013

Abstract

This paper is concerned with the problem of dissipative performance control under output regulation constraints for continuous-time descriptor systems. In this problem, an output is to be regulated asymptotically with the presence of an infinite-energy exo-system, while a specific dissipative performance from a finite external disturbance to a tracking error has also to be satisfied. Based on a generalized Sylvester equation, the asymptotical regulation objective is achieved and a specific structure of the resulting controller is deduced. Using this structure, the solution to the defined multi-objective control problem is characterized in terms of a set of linear matrix inequalities (LMIs).

1. Introduction

Over recent decades, there has been a visibly growing interest in the research of descriptor systems. This is mainly due to their extensive applications in large-scale systems networks, circuits, economic systems, chemical processes, robotics, aircraft modeling, and other critical fields [1,2]. A number of control issues have been successfully extended to descriptor systems and the related results have been reported, for instance, in [1–9] and the references therein.

*Corresponding author at: Department of Information Engineering, Zhejiang University of Technology, 288 Liuhe Road, Hangzhou, 310032 Zhejiang, PR China. Tel.: +86 57185290601.

E-mail addresses: yfeng@zjut.edu.cn (Y. Feng), myagoubi@mines-nantes.fr (M. Yagoubi), pchevrel@mines-nantes.fr (P. Chevrel).

0016-0032/$32.00
http://dx.doi.org/10.1016/j.jfranklin.2013.02.014

On the other hand, the well-known regulation problem in control has been studied by many scholars. Based on the seminal result, known as the internal model principle [10–12], exact asymptotic regulation is achieved by a structured controller containing a copy of the dynamics of the exo-system. Moreover, extensions of this scheme have been considered by integrating other performance objectives, for instance, H_2 and H_∞ performance. Such multi-objective problems have been extensively investigated in the literature [13–16]. In addition, the regulation problem has also been studied for descriptor systems. For example, in [1], the author provided a solution to this problem in terms of a set of nonlinear matrix equations depending on system parameters and some other parameters. In Ref. [17], a more clear-cut solution of this problem was obtained via solving a generalized Sylvester equation. Some scholars have also studied the regulation problem for nonlinear descriptor systems. See for instance [18,19].

Furthermore, the notion of dissipativity [20] plays an essential role in system and control theory both for theoretical considerations as well as from a practical point of view. Many important control issues can be formulated as dissipativity with quadratic supply functions, for instance, positive realness, bounded realness and circle criterion. Parallel to the conventional linear system theory, the dissipativity problem has also been extended to descriptor systems, just to mention a few, [4,21–24].

In spite of the vast literature on descriptor systems, few works have been concerned with the output regulation with other performance objectives. For example, Ref. [17] only tackled the output regulation problem under error feedback and no addition performance requirement was considered. The purpose of this paper is the design of a measurement output feedback controller to solve the problem of dissipative performance control subject to output regulation constraints for continuous-time descriptor systems. In this paper, a generalized Sylvester equation is proposed to achieve internal stabilization subject to asymptotic regulation constraints, and a specific structure of the resulting controller is deduced. Then, based on this structure, the additional dissipative performance objective is satisfied by using an LMI-based approach. The remainder of this paper is organized as follows. Section 2 recalls some basic notations of descriptor systems and formulates the problem. The regulator theory is extended to descriptor systems and the structure of the resulting controller is given in Section 3. Section 4 derives the solution to the dissipative performance control problem under regulation constraints via a set of LMIs. Finally, a numerical example is included in Section 5.

Notation: The superscript '$\star$' represents the complex conjugate transpose. Matrices identifiable from symmetry simply are abbreviated with '$*$'. We also define $\mathbf{He}\{P\}$ for $P^\top + P$. Moreover, for a matrix $\Lambda \in \mathbb{R}^{m\times n}$ with $m>n$, let $\Lambda^\perp \in \mathbb{R}^{(m-n)\times m}$ be any matrix satisfying $\Lambda^\perp \Lambda = 0$ and $\Lambda^\perp (\Lambda^\perp)^\top > 0$. Note that $\Lambda^\perp$ exists if and only if Λ has linearly dependent rows. For $m<n$, let $\Lambda^\perp \triangleq ((\Lambda^\top)^\perp)^\top$.

2. Problem formulation

2.1. Preliminaries

Let us consider the following descriptor system:

$$\begin{cases} E\dot{x}(t) = Ax(t) + Bv(t), \\ z(t) = Cx(t) + Dv(t), \end{cases} \tag{1}$$