Chapter 5
Fault detection in a belt-drive system

Abstract In this chapter a fault detection method is proposed to detect the belt breakdown in a belt drive system where it is assumed that a DC motor drives an inertial load through a belt. The proposed approach is based on a proportional reduced order observer (see Lemma 3.1) designed using differential algebraic techniques. Experimental results are given to evaluate the proposed approach.

5.1 Introduction

The high reliability required in industrial processes has created the need for detecting abnormal conditions while the processes are operating. These conditions are called faults and it is important to detect them in the early stages. Belt drive systems are ubiquitous in industry and they are used to drive fans, machine tools and many other mechanical devices. It is worth remarking that in most cases the belt works at constant speed. The most likely fault in belt drive systems with possible catastrophic consequences is belt breakdown.

Literature about fault detection in belt drive systems is rather scarce, in particular, the detection of belt breakdown. The fault detection problem in a drive belt system has been studied in [1] using parameter estimation techniques combined with heuristic knowledge from a human operator. The approach presented in that paper is powerful in the sense that both, the heuristic and the analytical knowledge, are combined through a knowledge-based fault diagnosis procedure. For the analytical part a Least Squares algorithm is employed for parameter identification and several parameters may be identified simultaneously, for instance, armature inductance, armature resistance, flux linkage, viscous and Coulomb friction and belt elasticity. A drawback of parameters estimation methods is the fact that a persistence of excitation condition is needed in order to obtain parameter convergence, i.e., if the belt drive system behaviour is such that the persistence of excitation condition is not fulfilled the parameter estimates do not converge to the true ones.
As an alternative to parameter estimation, in this chapter we propose a new approach to detect the breakdown of a belt in a belt drive system. Here, a proportional reduced order observer, designed via algebraic differential techniques, is employed for detecting the belt breakdown. An advantage of this approach is that the persistence of excitation condition needed in parameter identification is not longer necessary. Moreover, the resulting observer has linear dynamics and then it can be easily implemented using analog electronics or digital processors.

5.2 Statement of the problem

The model of a belt-drive system consisting of a DC motor connected to a load through a belt is given by the following equations

\[
\begin{align*}
J_1 \ddot{\theta}_1 + f_1 \dot{\theta}_1 + 2\rho (r_1 \theta_1 - r_2 \theta_2) r_1 &= \tau \\
J_2 \ddot{\theta}_2 + f_2 \dot{\theta}_2 + 2\rho (r_2 \theta_2 - r_1 \theta_1) r_2 &= 0
\end{align*}
\]

(5.1)

where:
- \( J_1 \): motor inertia
- \( J_2 \): load inertia
- \( f_1 \): motor friction
- \( f_2 \): load friction
- \( \rho \): belt elasticity coefficient
- \( \tau \): motor torque
- \( \theta_1 \): motor angle
- \( \theta_2 \): load angle
- \( r_1 \): radius of the pulley motor
- \( r_2 \): radius of the pulley’s load

The fault detection consists of determining the belt breakdown. In terms of model (5.1) the belt breakdown happens when the belt elasticity coefficient \( \rho \) is equal to zero. Under the above condition system (5.1) becomes

\[
\begin{align*}
J_1 \ddot{\theta}_1 + f_1 \dot{\theta}_1 &= \tau \\
J_2 \ddot{\theta}_2 + f_2 \dot{\theta}_2 &= 0
\end{align*}
\]

(5.2)

Using the following changes of variables:

\[
\begin{align*}
x_1 &= \dot{\theta}_1 \\
x_2 &= \dot{\theta}_2 \\
x_3 &= r_1 \theta_1 - r_2 \theta_2
\end{align*}
\]

system (5.1) may be written as