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The Approach to Design Control System for the Electric Drive with Flexible Mechanics

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Abstract

Research in this paper is devoted to optimal control design approach for electric drives used in mechanical systems with significant flexibilities, such as robot manipulators with long and flexible arms or similar setups. All electric drive systems are divided into three typical structures, providing the regulation of torque, speed and position. Transfer functions of the dynamic stiffness of mechanical characteristics are recorded. It is shown that for any structure of the electric drive there is an optimal stiffness of the mechanical characteristic, which provides the maximum damping capacity of elastic vibrations by means of the electric drive. Mechanical oscillations given rise to torsional and bending deformations are considered in the article. Unfortunately, the parameters of the mechanical part of the electric drive, which depend on the optimal stiffness, are often unknown, or they change in operation. In this article recommendations on the construction of electric drive systems using artificial intelligence elements have been developed. In order to achieve maximum damping capabilities and to increase dynamic positioning accuracy, various approaches are introduced. Given recommendations should help engineers to select effective control strategy during design phase, whenever target mechanical system is considered to be flexible and requirements for positioning accuracy are high. Simulations were made in MATLAB / Simulink environment.

Keywords: Hot- variable speed drives; flexibility; electromechanical systems; control systems; damping; fuzzy control; neural networks.

1. Introduction

Desire to improve dynamic performance of an actuator leads to the need of reducing weight and dimensions of a mechanism [1]. In this case, deformations of bodies begin to play a significant role due to corresponding increase inflexible mechanical vibrations, which could not be neglected from now, causing positioning accuracy to decrease,

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positioning transient time to increase and mechanics Mean time between failures (MTBF) to increase because of additional dynamical stresses. Due to the abovementioned reasons, finding a possibility to damp flexible vibrations by means of electric drive becomes critically important [2,3].

Application of intellectual control systems in electrical drives when flexible joints presented has been the subject of numerous studies, especially in robotics area [4-6].Particularly this research is dedicated to generalized theoretical approach in designing optimal control systems for the abovementioned flexible systems in case of lumped and distributed parameter models [1,5,7].

Electric drive is an electromechanical system consisting of electric and mechanical parts and, as well known, its properties are determined by the child elements included in it, as well as the links between them. Properties of an actuator, when mechanical part is represented in the form of a rigid mechanical link with known parameters, is well studied in[1,3,6,8-10].In theory of electric drives, the concept of dynamic stiffness was introduced and used to control coordinates by means of utilizing predefined model structures with given transfer functions [11].

With static torque control as in (1):

$$W(p) = \beta_c \frac{T_1 p + 1}{(T_2 p + 1)(T_3 p + 1)} \tag{1}$$

With a static speed control as in (2):

$$W(p) = \frac{\beta_c}{T_1 p + 1} \tag{2}$$

With a static speed control and position control as in (3):

$$W(p) = \frac{\beta_c (T_1 p + 1)}{T_2 p (T_3 p + 1)} \tag{3}$$

Using gearless variable speed drive significantly impacts on speed controller’s bandwidth due to changing mechanical parameters. For certain applications (drilling rigs, industrial robots, cranes) equivalent moment of inertia does not remain constant and follows complicated and usually unknown pattern, as well as non-linearity in bearings and flexible mechanical parts bring unwanted vibration modes to the end-effector positioning. It becomes impossible to achieve desired quality of control with such predefined structures.

2. The new control system

Let us take three known basic approaches of flexible mechanical system’s representation:

- lumped parameter model with fixed mechanical properties
- lumped parameter model with variable mechanical properties
- distributed parameter model.

First approach is to describe mechanical system as a lumped parameter model, so called flexible joint model, considering flexible couplings and joints [1,2]. Rigid bodies are connected by torsion spring-dampers and Lagrangian formulation is applied. Having a variable speed drive performing positioning of given system, some of arising flexible modes are damped due to the properties of electric motor. It was found that there is always an optimal ratio when highest damping capability could be achieved. In Fig. 1, we could see the relation between logarithmic damping decrement λ and stiffness β of an electric motor’s mechanical characteristic.