Institutionen för systemteknik
Department of Electrical Engineering

Examensarbete

Investigation of Control Approaches for a Rotational Piezo-based Actuator for Accurate Positioning Application Operations at CERN

Examensarbete utfört i Mekatronik
vid Tekniska högskolan vid Linköpings universitet
av

Niklas Ericson

LiTH-ISY-EX--YY/NNNN--SE

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Department of Electrical Engineering
Linköpings universitet
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Undersökning av ett problem

Investigation of Control Approaches for a Rotational Piezo-based Actuator for Accurate Positioning Application Operations at CERN

Författare
Author

Niklas Ericson

Sammanfattning
Abstract

Det här som vi har hållit på med är jätteviktigt faktiskt och det vi gjort blev bara sååå bra. Kanske inte helt otippat, men det glass är sååå gott!

Förresten har vi blivit bäst på att skriva rapporter, så nu ska ska vi inte gå in närmare på några detaljer såhär i sammanfattningen.

Nyckelord
Keywords

problem, lösning

Sammanfattning

Det här som vi har hållit på med är jätteviktigt faktiskt och det vi gjort blev bara sååå bra. Kanske inte helt otippat, men det glass är sååå gott!

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Abstract

If your thesis is written in English, the primary abstract would go here while the Swedish abstract would be optional.

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Notation

Några mängder

Notation	Betydelse
$\mathbb{N}$	Mängden av naturliga tal
$\mathbb{R}$	Mängden av reella tal
$\mathbb{C}$	Mängden av komplexa tal

Förkortningar

Förkortning	Betydelse
CERN	European Organization for Nuclear Research
STM	Scanning Tunneling Microscope
AFM	Atomic Force Microscope
LHC	Large Hadron Collider
PEA	Piezoelectric actuator
PID	Proportional, Integral, Differential (regulator)
DOF	Degrees of Freedom

1

Introduction

1.1 Background

The piezoelectric effect is a phenomenon that arises in certain solid materials when an electric potential is generated in response to applied mechanical stress. The effect was first discovered by Jacques and Pierre Curie in 1880 when they found that applying pressure to a quarz crystal generates electrical potential. Today, the effect is commonly encountered in daily life and utilized in for example lighters, buzzers and loudspeakers

Smart materials such as piezoelectric and magnetostrictive materials are commonly used in precision actuators today due to their ability to convert electrical energy into mechanical energy. Piezoelectric materials have been commercially available for almost 45 years and have become indispensable for the nanopositioning industry [6]. In cases where a relatively small displacement range is required (travel ranges up to 500 μm) a piezo electric device is the actuator of choice due to its fast response, high resolution and its ability to generate large mechanical forces for small amounts of power in compact designs [5].

High precision positioning systems are vital in e.g. scanning tunneling microscopes (STM), atomic force microscopes (AFM) and in semiconductor lithography. In AFM, for instance, high precision positioning is required to control the vertical position of the scanning probe to keep the force constant between the sample surface and the probe tip. An topographical image of the sample is obtained by raster-scanning the probe over the sample surface and plotting the vertical displacement against the probe's x-y position. A positioning system that keeps the force constant down to an atomic-scale resolution is thus inevitable in order to obtain a high resolution image without damaging the sample [5].

In the UA9 Experiment located at CERN (European Organization for Nuclear Research) a high precision positioning system is required for the control of a

piezo-actuated rotational stage. The stage uses a piezo electric linear stack actuator to displace a flexible lever arm mechanism which generates the rotational movement.

1.2 Purpose and Goal

Crystalline solids have the ability to constrain the directions that particles take as they pass through, this is commonly called the "channelling" property. The UA9 collaboration at CERN is investigating how tiny bent crystals can help to steer particle beams in modern hadron colliders such as the Large Hadron Collider (LHC) [4]. In high energy colliders, such as the LHC, particles drift outwards creating a beam halo. These particles surrounding the beam, can be lost and cause damage to sensitive parts in the accelerator. By using bent crystals, halo particles can be efficiently extracted from the beam and collected by absorbers further away, reducing the complexity of the system. One major difficulty that aries is that the higher the energy of the particle, the lower the angular acceptance for channeling. Hence, a high precision positioning mechanism with a high angular accuracy is required. The rotational stage (with a range of 20 mrad) is of necessity to be able to track reference trajectories at ramp rates of 100 μrad/s and reject external disturbances to maintain a maximum tracking error of ±1 μrad.

This project aims to identify the possible control approaches that could be applicable to this problem to achieve the desired performance.

1.3 Prospective challenges

First of all, piezoelectric actuators show strong nonlinear properties such as hysteresis and creep (drift), which have to be compensated for. Moreover, the mechanical flexural structure in combination with the piezo electric characteristics leads to a highly resonant structure. Making it difficult to achieve the desired performance while operating the rotational stage within noisy environments, e.g. LHC, with external disturbances such as ground vibrations.

Furthermore this rotational stage is attached to a linear stage which is composed by a leadscrew, a stepping motor and an axel. The linear movement adds additional perturbation to the rotational stage due to imperfections in the leadscrew and detent torque and stepping nature of the motor.

Finally the system dynamics also show linear position dependence requiring a controller that is robust to such variations.

1.4 Related work

One attempt to achieve the desired performance has already been made. The proposed controller, presented in [3] delivers reasonable performance but does not fulfill the requirements during movement. The authors proposes a PID controller in combination with a pre-filter, and a hysteresis compensator. The controller has

shown high disturbance rejection at the first resonance peak as well as good tracking performance.

1.5 Outline

en preliminär problemformulering satt i relation till litteraturbasen

2

Method

en preliminär beskrivning av angreppssätt

2.1 Literature review

Here follows a short review of the planned literature base that will be used in this thesis.

Controller Design and Verification for a Rotational Piezo-based Actuator for Accurate Positioning Applications in Noisy Environments, Butcher M. and A. [3]

The authors have adopted a Hammerstein structure, allowing them, in principal, to decouple the nonlinear hysteresis from the linear system dynamics.

[2]
[1]
[7]
planerad litteraturbas

2.2 Timeplan

en tidplan för examensarbetets genomförande inklusive planerade datum för halvtidskontroll och framläggning

3

Result

preliminära resultat som kan demonstreras vid halvtidskontroll

4

Conclusions

Sätt av ett kort kapitel sist i rapporten till att avrunda och föreslå rikningar för framtida utveckling av arbetet.

Appendix

A

definitions

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abbreviation, ix

CERN
abbreviation, ix

DOF
abbreviation, ix

LHC
abbreviation, ix

PEA
abbreviation, ix

PID
abbreviation, ix

STM
abbreviation, ix