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Design of an Active Vibration Control for a Roller System

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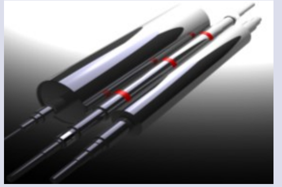
Overview

• Introduction
• Simulation
& Control Design
• Test results
• Summary & Outlook



Vibrations in Flexographic Printing

- Efficiency of flexographic printing processes
- Increased web velocity and/or roller width
- Vibrations
- Streak print defects
- Active vibration damping

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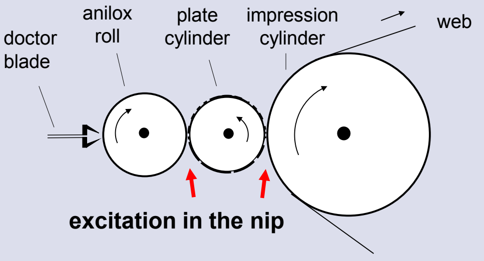
Roller System in a Flexographic Printing Machine



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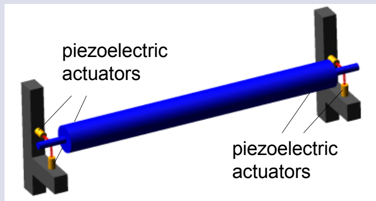
Piezoelectric Actuators in the Bearings

- large forces up to 45000 N (push)
- pre-load springs
- small displacements $x \leq 200\ \mu m$
- high dynamics up to 2.5 kHz
- no static forces



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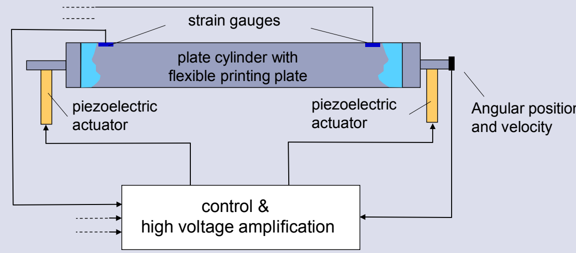
Control Structure



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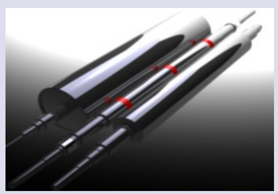

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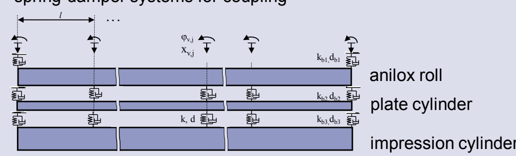
Modelling of a Roller System

- continuum elastic bending beams
- local discretisation
- finite element method
- spring-damper systems for coupling



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Modelling of a Roller System (cont.)

$$M\ddot{x}+D\dot{x}+Kx=f$$

where

$$K=K_r+K_c$$

$$D=\alpha K+\beta M \quad \text{(Rayleigh formula)}$$

α, β: constants (experimentally determined)

- x: vector of degrees of freedom
- f: excitation vector
- M: mass matrix
- K: total stiffness matrix
- K_r: stiffness matrix of rollers
- K_c: additional stiffness matrix (coupling and bearings)
- D: damping matrix

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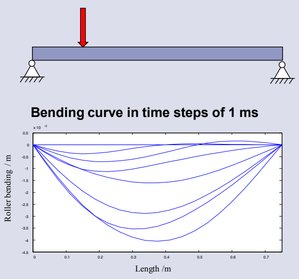
Open Loop Simulation Examples

- Matlab/Simulink
- single roller with 20 discretisations
- response to a local force impulse



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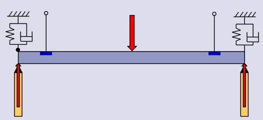
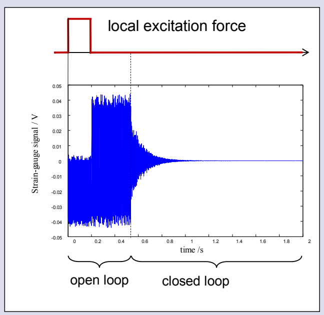
Closed Loop Simulation Examples



- flexible bearings enable small displacements
- bearings modelled as spring-damper systems
- strain gauges
- piezoelectric actuators apply damping forces
- PD-Controller



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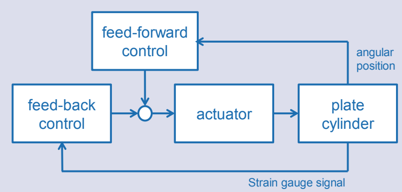
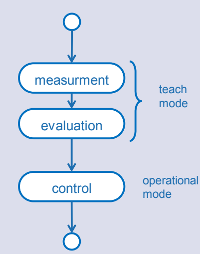
Control of Periodic Disturbances

- periodic disturbances yield periodic control signals
- predictable force portion according to angular position of plate cylinder ⟶ feed-forward control
- feed-back control of the remaining control deviations





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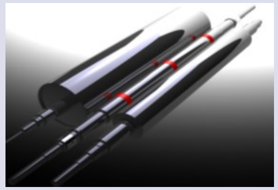

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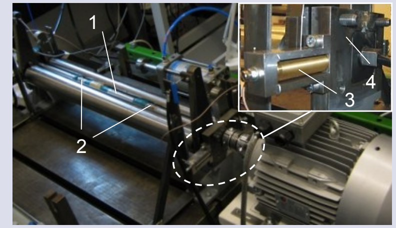
Small Scale Test Bed

- down scaled geometry

  1: plate cylinder
  2: strain gauges
  3: piezoelectric actuators
  4: flexible bearing
- eigenfrequencies simular to an industrial plant



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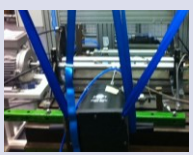
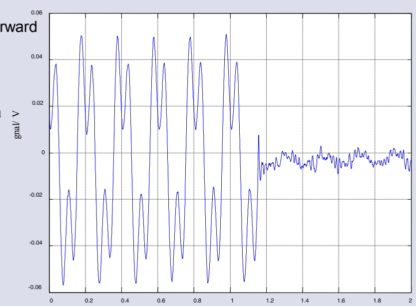
First Test Results

- combined periodic feed-forward compensation and PD feed-back control
- non-rotating mode with periodic disturbances by a shaker





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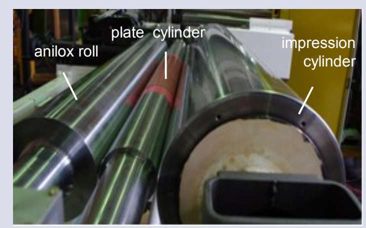
Full Scale Test Bed

- anilox roll and plate cylinder taken from an industrial plant
- currently under recon-struction for integration of the actuators and flexible bearings



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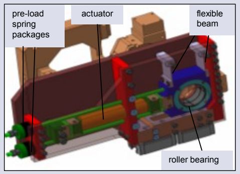
Active Bearings

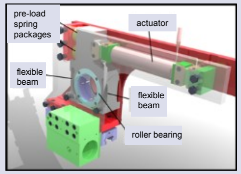
- flexibility for small displacements
- constructive constraints

Side A



actuator presses directly on the plate cylinder

Side B



actuator above the plate cylinder

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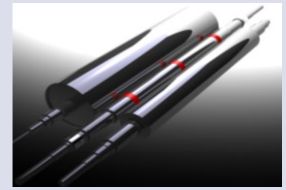

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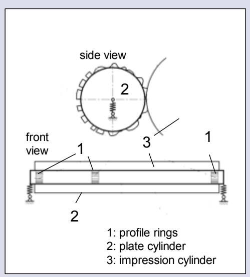
Outlook

- detailed evaluation at the test beds
- modal control
- adaptive control
- transfer to industrial plant
- periodic counter forces by means of profile rings
  - rotating with the plate cylinder
  - counter force generated passively when rolling against the impression cylinder



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Summary

- roller systems in flexographic printing machines
- active vibration damping with piezoelectric actuators
- simulation based control design
- feed-forward compensation of periodic disturbances
- first test results at small scale test bed
- full scale test bed under construction