Aalborg University

Design of non-linear controller for hysteresis cancellation

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Group:
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AALBORG UNIVERSITY
STUDENT REPORT

Title:

Model predictive control of flow and concentration of sewage in a sewer system

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Abstract:

Preface

This report has been created by Jacob Naundrup Pedersen. The project is performed on the 3rd semester of the master control and automation at Aalborg University. The project is constructed in an internship at Grundfos. Grundfos has contributed with the test setup for the project. The student has followed two courses at Aalborg University, non-linear systems and machine learning.

The report is intended for people with a background knowledge corresponding to a third-semester master student at Control and Automation, Aalborg University. The following programming languages MATLAB and Simulink are used in the project. All graphical elements in the report are constructed by the author. Otherwise, a reference to the source, is stated in the figure text.

Sources are indicated by [name,year], and can be found in the bibliography list at the given [name,year].

Jacob Naundrup Pedersen

Contents

Nomenclature

Abbreviation

Abbreviation	Definition
AAU	Aalborg University

Symbols

Symbol	Description	Units
A	Area	m^2
q	Water flow	m^3/s
D	Diameter meter	m
r	Radius	m
ω	Velocity	rad/s
U_a	Voltage	J/C
N	Gear ratio	
τ	Torque	Nm
i_a	Current	C/s
R_a	Resistance	Ω
L_a	Inductor	H
K	Electromotive force	$\frac{V \cdot s}{rad}$
F	Force	N
θ	Angle	rad
Δp	Differential pressure	bar
K_{vs}	Conductivity for fully-open valve	m^3/h
v	Velocity	m/s
m	Mass	kg
V	Volume	m^3
ρ	Density	kg/m^3
l	Length	m
f	Friction factor	
h_f	Surface resistance	m
g	Gravitational acceleration	m/s^2
k_L	Form-loss coefficient	
h_l	Form resistance	m
h	Pressure	m
J	Inertance	kg/m^4
a_n	Pump parameters	
T	Temperature	$^\circ C$
c	Specific heat capacity	$\frac{J}{kg \cdot K}$
m_n	Mass flow	kg/s

Introduction 1

Sewers were created to solve the seemingly simple problem of removal of wastewater. The first sewers, registered, dates back to 7000 B.C. in urban settlements and were created to remove wastewater from houses and surface runoff created by rain water. To avoid clogging and wear of the sewers grit chambers was constructed. They work by slowing the flow of sewage in long narrow channels making the solids, such as sand, end up as sediments in the channels due to gravity. Complexity of sewers increased in ancient Rome where large underground systems were created leading to the the main sewer system called "Cloaca Maxima" making it possible to have latrines with running water within households, though mostly made available for the rich. Waste were still thrown onto streets as people during night time did not want to put in the effort to properly dispose of the waste. Because of that the ancient Rome suffered from illnesses related to indisposed waste lying in the streets. The hygienic aspect of waste were not considered until the 19th century, where several European cities saw large outbreak of cholera causing the deaths of millions. The growth in waste caused the expansion of 26 kilometer sewer network in Paris to 600 km during the 19th century but it is not until the start of the 20th century that the chemical and microbial processes in sewers are considered [Thorkild Hvitved-jacobsen,].

A sewer system is used for removing wastewater originating from households, industries and runoff from different urban areas. It is collected in the sewers and transported through the sewer network to a wastewater treatment plant, where the wastewater will go through a filtering process and thereafter be discharged into to a receiving water system. The European definition of a sewer network is: *A sewer system is a network of pipelines and ancillary works that convey wastewater from its sources such as a building, roof drainage system, or paved area to the point where it is discharged into a wastewater treatment plant or directly into the adjacent environment (BS EN 752.1, 1996)*[1]. Sewer network consist of pipes (sewer lines) and different installations and structures such as inlets, manholes, drops, shafts and pumps.

Sewer network date back to the beginning of urban settlements. These networks was used to remove either wastewater from houses or surface runoff in populated areas [2]. Around 2500-2000 BC the settlement of the Indus Valley Civilization, located in the west Pakistan, buildings shows bathing and latrine facilities. Where a sewer system equipped with a grit chamber is used to remove unwanted materials from the water. A grit chamber is a long narrow tank designed to slow the flow and thereby solids such as sand will settle out of the water due to gravity. At the time these grit chambers was important for a proper function of the sewerage.

Up until the seventeenth century most large cities in Europe had underdeveloped drainage infrastructure. Hereafter the development of underground sewer networks started. Paris was one of the first to develop a efficient sewer network. In the period of the French revolution, around 200 years ago, the total length of sewer network in Paris was only

[1] FiXme Note: find kilden, dette er en citering fra biblen, hvor han refer til BS EN 752.1
[2] FiXme Note: kilde

26 km long. This was extended to 600 km in 1887. Which indicate the need of removing wastewater from the growing cities. The reasons for constructing these underground sewers, was to collect the wastewater, due to the malodorous smell from open sewers, cesspools, privies and furthermore, freeing space in the densely packed streets of the populated cities, thereby giving space to roads, housing etc.

Bibliography

[Thorkild Hvitved-jacobsen,] Thorkild Hvitved-jacobsen, Jes Vollertsen, A. H. N.

Appendix A