Aalborg University

Model Predictive Control of a Sewer System

Control and Automation:
Master Thesis

Group:
CA9-1030

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Master thesis
Control and Automation
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Title:

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

Abstract:

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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 the population, without immediate access to a latrine in their household, during night time did not want to put in the effort to properly dispose of the waste. Because of this the ancient Rome suffered from illnesses related to waste lying in the streets. The hygienic aspect of proper disposal of wastewater in relation to drinking water 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 furthermore 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. The microbial cause of cholera were identified by the German doctor Robert Koch in 1883, a discovery for which he in 1905 received the Nobel Prize in physiology and medicine. The growing industries and technological progress in the 20th century meant that more chemicals were disposed into the sewers having severe consequences for the organic life downstream of the receiving waters. Wastewater treatment plants were introduced to reduce the pollution, but several countries did not have any wastewater treatment plants before after World War II. Today disposal of sewage and setup of wastewater treatment plants is a given part of construction of new settlements, even in poor regions of the world [Hvitved-Jacobsen et al., 2013].

1.1 Chemical process

[1]

1.1.1 Chemical reactions in a sewer

A wastewater treatment plant receive not only what is discharged into the sewer from the industry and households but also the chemical and microbial reactions that occurs in a

[1] FiXme Note: Illustrering af fig 1,1 hvitved og dertil beskrivelse af den, for at give et overblik over kloakker og dens processer

sewer. Within these sewers different redox reactions occurs. Redox reaction is the transfer of electrons between two compounds at a atomic or molecular scale. By transferring electrons from one compound to another new compounds will rise, such as hydrogen sulfide which is know for it malodorous smell of rotten eggs. These redox reactions are determine to a great extend by the design of the sewer.

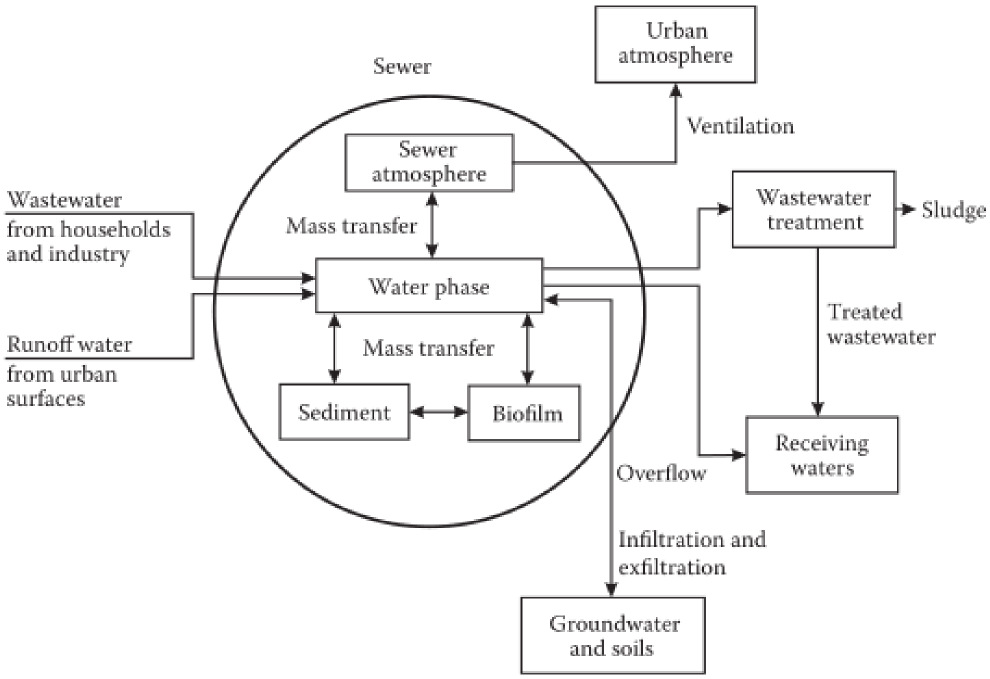

Figure 1.1: Illustrates how the wastewater flows from the industry and households to the treatment plant. [2]

1.1.2 Wastewater treatment plant

1.2 Sewer construction

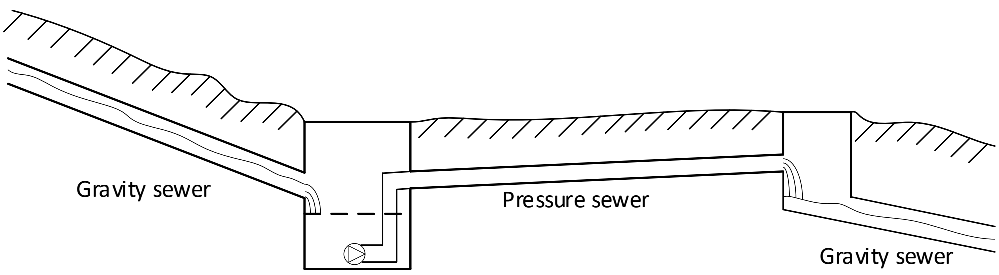

Figure 1.2: Illustrate different methods for transportation of sewage.

System description 2

Bibliography

[Hvitved-Jacobsen et al., 2013] Hvitved-Jacobsen, T., Vollertsen, J., and Nielsen, A. H. (2013). *Sewer processes: microbial and chemical process engineering of sewer networks.* CRC press.

Appendix A

Rettelser