Optimising Municipal Sewage Networks-Using Computational Fluid Dynamics

Case study: Tororo Municipality, Uganda

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DECLARATION

I **ESEMU JOSEPH NOAH**, hereby certify that this dissertation is a result of my original research work and to the best of my knowledge it has never been submitted for any degree award in any other university before and I present it without any reservations for external examination.

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APPROVAL

This research work culminating into this dissertation was conducted under my guidance and supervision.

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DEDICATION

I would like to dedicate this work to the Almighty God for his grace, my Mother Akol Regina, Late Father Mzee Ebyeu Zerubbabel and all my brothers and sisters who have always strived to show me the true value of education. My dear wife, children and entire family, for all your support and inspiration.

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ACRONYMS AND ABBREVIATIONS

ACRONYMS

1D	One Dimensional
2D	Two Dimensional
3D	Three Dimensional
CFD	Computational Fluid Dynamics
CSF	Continuum Surface Force
CVs	Control Volumes
DIC	Diagonal-based Incomplete Cholesky
DILU	Diagonal-based Incomplete Lower-Upper
DNS	Direct Numerical Simulation
FVM	Finite Volume Method
INS	Incompressible Navier-Stokes Equation
FDM	Finite Difference Method
FEM	Finite Element Method
K-Epsilon	Kappa-Epsilon
NS	Navier-Stokes Equation
NWSC	National Water and Sewerage Corporation
OpenFOAM	Open source Field Operation And Manipulation
PbiCG	Preconditioned Bi-Conjugate Gradient

PDEs	Partial Differential Equations
PISO	Pressure Implicit with Splitting of Operators
PIMPLE	Combination of PISO and SIMPLE
PCG	Preconditioned Conjugate Gradient
RANS	Reynolds Average Navier-Stokes
RAS	Reynolds Average Simulation
RUFORUM	Regional Universities Forum for Capacity Building in Agriculture.
SIMPLE	Semi-Implicit Method for Pressure-Linked Equations
VOF	Volume of Fluid

ABSTRACT

Two-phase pipe flow is a common occurrence in many industrial applications such as sewage, water, oil and gas transportation. Accurate prediction of liquid velocity, holdup and pressure drop is of vast importance to ensure effective design and operation of fluid transport systems. In this dissertation, simulations of a two-phase flow of air and sewage (water) are performed using open source software OpenFOAM. Numerical Simulations have been performed using varying dimensions of pipes as well as their inclinations. A Standard k-ε turbulence model and the Volume of Fluid (VOF) free water surface model is used to solve the turbulent mixture flow of air and sewage (water). Results show that the flow pattern behaviour is influenced by the pipe diameters as well as their inclination. A two dimensional, 0.5m diameter pipe of 20m length is used for the CFD approach based on the Navier-Stokes equations. It is concluded that the most effective way to optimize a sewer network system for Tororo Municipality conditions, is by adjusting sewer diameters and slope gradients and expanding the number of sewer network connections of household and industries from 535 (i.e. 31.2% of total) to at least 1,200 (70% of total).

Keywords:

Computational Fluid Dynamics (CFD); OpenFOAM; Optimal Design problem; Municipal Sewer network, Simulation, diameter, flow rate and pressure drop.

CHAPTER ONE

INTRODUCTION

1.1 Background

In urban development history, Municipal Sewage systems were built to rapidly collect rain runoff, wastewater and sewage. These networks consist of pipes, pumping stations, force mains, manholes, and other facilities required to collect and transport wastewater (Moeini & Afshar, 2017). Research on urban drainage pipelines focuses on hydraulics such as pipe slopes and flow rate so that sewage and faecal sludge are to be delivered efficiently (Han, 2012). The flows at or in the proximity of these structures are typically highly turbulent and often characterized with changes between open channel (free surface) and pressurized conditions. Such turbulent flows frequently involve complex interactions between air and water (Lopes, P., 2013) as in the case of manholes with multiple in/out pipes, stepped spillways, and flow network structures. The latter structures are typically composed by an entrance manhole and inflow, overflow, and underflow conduits. The main design challenge of the network structure is the allowance of overflows only after underdrain capacity is exceeded, while minimizing head losses that reduce the underdrain flow capacity. A second challenge is the prevention of significant backwater effects.

In hydraulic structures such as sewers and spillways, the air in the flow is important, perhaps an indispensable design factor (Leandro & Carvalho, 2013). The presence of air in wastewater (1) increases the bulk of the flow thus influencing the height of the chute side walls, (2) prevents the damage of the chute caused by cavitation, (3) increases the momentum when the air within the boundary layer reduces the shear stress and (4) re-oxygens the water flow which contributes to the downstream river quality and the preservation of aerobic species (Leandro & Carvalho, 2013).

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