DESIGN AND CONSTRUCTION OF A CONTROL SYSTEM FOR A WASTEWATER TREATMENT MODEL

By

Giovanni Aditya Sutedjo

A Bachelor's Thesis
Submitted to the Faculty of Engineering

MECHATRONICS Department

in partial fulfillment of the
requirements for the Degree of

BACHELOR OF SCIENCES
WITH A MAJOR IN MECHATRONICS

SWISS GERMAN UNIVERSITY

SWISS GERMAN UNIVERSITY
Edu Town, BSD City
Tangerang – 15339
Island of Java, Indonesia
www.sgu.ac.id

July 2010

Revision after the Thesis Defense on 10th August 2010

STATEMENT BY THE AUTHOR

I hereby declare that this submission is my own work and to the best of my knowledge, it contains no material previously published or written by another person, not material which to a substantial extent has been accepted for the award of may other degree or diploma at any educational institution, except where due acknowledgement is made in the thesis.

SGU®
SWISS GERMAN UNIVERSITY

_____ _____

Giovanni Aditya Sutedjo Date

Approved by:

_____ _____

Ir. Arko, Ph.D Date

_____ _____

Dr. Ir. Tutuko Prajogo, MSMfgE Date

_____ _____

Chairman of the Examination Steering Committee Date

ABSTRACT

DESIGN AND CONSTRUCTION OF A CONTROL SYSTEM FOR A WASTEWATER TREATMENT MODEL

By

Giovanni Aditya Sutedjo

SWISS GERMAN UNIVERSITY
Bumi Serpong Damai

Ir.Arko,Ph.D, Advisor
Dr. Ir. Tutuko Prajogo, MSMfgE, Co-Advisor

The thesis research serves as an educational purpose of water treatment process. The purpose is achieved by building a visible small scale wastewater treatment plant as a real example of the water treatment process. Visibility of the internal model is required to allow direct visual inspection of the treated water, in addition to monitoring by some sensors. The methods of the research start from choosing the wastewater that is going to be treated. After that, the research continues by taking and testing the sample, designing the treatment processes, building the working model of wastewater treatment plant followed by integrating it with online control system. During the test, findings of the mechanical structure difficulty showed up. With proper analysis of root cause, an improvement has been devised. The testing of the whole process is still in progress to observe key processes as well as parameters affecting the overall performance of the water treatment. In conclusion, the visible waste water treatment system has been built, allowing extended test to be performed and analysed. Additional sensors can be added to the system for further improvement, without signifance changes to the model.

Keywords: wastewater, water treatment, control system, HMI, model

DEDICATION

I dedicate this thesis to my family, especially my father for his support and never give up attitude that strengthen me in hard times.

SWISS GERMAN UNIVERSITY

ACKNOWLEDGMENTS

The author wishes to thanks My God, Jesus Christ whose grace and blessing never ceased to exist in my life.

The author also would like to thanks Ir. Arko, Ph.D for the ideas and for being a good advisor despite the hectic days he has to go through, and also to Dr. Ir. Tutuko Prajogo, MSMfgE for being a co-advisor whose guidance to break down the steps helps the author to finish the thesis work.

The author would also like to thanks Mr. Dede T. K. Saputra and Tutun Nugraha for the helps during the laboratory testing and for the helps to give an understanding of the water treatment system and to define the processes of the thesis work of the author.

The author would like to thanks Dipl.Ing- Garry Jonathan for his help with the tanks and to Mr. Imam for the cooperative work during the assembly process of the tanks.

The author would like to thanks the author's family for their support and for the faith that they have in the author, and for all the author's family and leaders in Abbalove Serpong, for Mr. Sumarno Kosasih and Mrs. Soen Lan for the concerns and supports, and especially for Eunike Kosasih and Kevin Kusumo for the great time we shared together and for the unconditional loves they give.

This thesis is worked on by 2 people, between the author and the author's colleague, namely Muhammad Falah and the author would like to say a special thanks for being a supportive and great team mates in the finishing process of the thesis project.

SGU ®
SWISS GERMAN UNIVERSITY

TABLE OF CONTENTS

STATEMENT BY THE AUTHOR....2
ABSTRACT....3
DEDICATION....4
ACKNOWLEDGMENTS....5
TABLE OF CONTENTS....6
LIST OF TABLES....10
LIST OF FIGURES....10
CHAPTER 1 - INTRODUCTION....12
1.1 Thesis Introduction....12
1.2 Background....13
1.3 Thesis Objective....13
1.4 Scopes of Thesis....13
1.5 Limitations....13
1.6 Thesis Organization....14
CHAPTER 2 - LITERATURE REVIEW....15
2.1 The Global Needs of Water....15
2.2 Water Treatment....15
2.2.1 A Visit to Industrial Water Treatment Plant (WTP)....16
2.2.1.1 Ventury Chamber....16
2.2.1.2 Coagulation....17
2.2.1.3 Flocculation....17
2.2.1.4 Sedimentation....18
2.2.1.5 Filtration....18
2.2.1.6 Disinfection....19
2.2.1.7 Distribution....19
2.2.2 Wastewater Treatment Classification....19
2.2.2.1 Sewage or domestic wastewater treatment....20
2.2.2.2 Industrial wastewater treatment....20
2.2.3 Water Treatment Common Processes....20
2.2.3.1 Aeration....20
2.2.3.2 Coagulation / Flocculation....21
2.2.3.3 Sedimentation....22
2.2.3.4 Filtration....23
2.2.3.5 Disinfection....24
2.2.4 Wastewater Treatment Parameter....25
2.2.4.1 pH (potential of Hydrogen)....25
2.2.4.2 Turbidity....26
2.2.4.3 Dissolved Oxygen (DO)....27
2.2.5 Waste Water Categories....29
2.2.5.1 Hospital Waste Water....29
2.2.5.2 Domestic Waste Water....29
2.2.5.3 Industrial Waste Water....29
2.2.6 Chemical Reagents....30
2.2.6.1 Potassium Permanganate [$KMnO_4$]....30
2.2.6.2 Aluminium Sulphate [$Al_2(SO_4)_3$]....30
2.2.6.3 Hydrated Lime [$Ca(OH)_2$]....30
2.2.6.4 Chlorine [Cl_2]....31

2.2.6.5 Polyphosphate [$Na_5P_3O_{10}$] 31
2.2.6.6 Fluoride (F^-) 31
2.2.7 Processed Water Categories 32
2.2.7.1 Disposable Water 32
2.2.7.2 Drinkable water 32
2.2.7.3 Bottled drink water 32
CHAPTER 3 - METHODOLOGY 33
3.1 System Design Overview 33
3.2 Sample Testing 33
3.2.1 pH level 34
3.2.2 Turbidity 34
3.2.3 Dissolved Oxygen Level 34
3.2.4 Color 34
3.2.5 Sedimentation Time 34
3.3 Detail Design of Water Treatment Plant Model 35
3.3.1 Detail Water Treatment Plant Model Diagram 36
3.3.2 Mechanical Design 38
3.3.2.1 Solid Separation Chamber 39
3.3.2.2 pH Control Tank 39
3.3.2.3 Aeration Tank 40
3.3.2.4 Sedimentation Chamber 1 40
3.3.2.5 Coagulation Tank 41
3.3.2.6 Sedimentation Chamber 2 41
3.3.2.7 Monitoring Tank 42
3.3.2.8 Motor Housing, Shaft, and Propeller 43
3.3.2.9 Dosing Tank 43
3.3.2.10 System Support 44
3.3.2.11 Piping System 45
3.3.3 Electrical Design 45
3.3.3.1 Sensors 45
3.3.3.2 Actuators 56
3.3.3.3 Controllers 60
3.3.4 Programming Strategy 65
3.3.4.1 Microcontroller programming 65
3.3.4.2 HMI programming 70
3.3.5 Testing and Integrating Strategy 72
3.3.6 Summary 73
CHAPTER 4 – RESULT & DISCUSSION 74
4.1 Sample Testing Result 74
4.1.1 pH level 75
4.1.2 Turbidity 75
4.1.3 DO Level 76
4.1.4 Color 76
4.1.5 Sedimentation Time 77
4.2 Result 78
4.2.1 Mechanical Design Result 78
4.2.1.1 Solid Separation Chamber 78
4.2.1.2 pH Control Tank 82
4.2.1.3 Aeration Tank 83

4.2.1.4 Sedimentation Tank 1 84
4.2.1.5 Coagulation Tank 86
4.2.1.6 Sedimentation Tank 2 86
4.2.1.7 Monitoring Tank 87
4.2.1.8 Motor Housing, Shaft, and Propeller Result 88
4.2.1.9 Dosing Tank 89
4.2.1.10 Support system 89
4.2.2 Electrical Design Result 92
4.2.2.1 Sensors 92
4.2.2.2 Actuators 94
4.2.2.3 Controller 98
4.2.3 Programming Result 99
4.2.3.1 Microcontroller Programming 99
4.2.3.2 HMI Programming 100
4.2.4 Testing and Integrating System Result 102
4.3 Findings and Discussion 103
4.3.1 Mechanical Findings 103
4.3.1.1 Tanks Leakages 103
4.3.1.2 Support System 105
4.3.1.3 Piping System 109
4.3.2 Electrical Findings and Discussion 109
4.3.3 Programming Findings and Discussion 110
CHAPTER 5 - CONCLUSION AND RECOMMENDATION 111
5.1 Conclusion 111
5.2 Recommendations 111
GLOSSARY 112
REFERENCES 113
APPENDIX A – TECHNICAL DRAWING (2D) 116
A.1 FULL TANKS ASSEMBLY 116
A.2 TOP VIEW FULL TANKS ASSEMBLY 117
A.3 ISOMETRIC VIEW FULL TANKS ASSEMBLY 118
A.4 BOTTOM VIEW FULL TANKS ASSEMBLY 119
A.5 SOLID SEPARATION CHAMBER OUTER WALL 120
A.6 SOLID SEPARATION CHAMBER OUTER SIDE WALL 1 121
A.7 SOLID SEPARATION CHAMBER OUTER SIDE WALL 2 122
A.8 SOLID SEPARATION CHAMBER BASE 123
A.9 SOLID SEPARATION CHAMBER COVER 124
A.10 SOLID SEPARATION CHAMBER INNER WALL 125
A.11 pH CONTROL TANK INNER WALL 126
A.12 pH CONTROL TANK WATER WAY 127
A.13 pH CONTROL TANK BASE 128
A.14 AERATION TANK OUTER WALL 1 129
A.15 AERATION TANK BASE 130
A.16 AERATION TANK OUTER WALL 2 131
A.17 SEDIMENTATION CHAMBER 1 INNER WALL 132
A.18 SEDIMENTATION CHAMBER CENTER BASE 133
A.19 SEDIMENTATION CHAMBER BASE 1 134
A.20 SEDIMENTATION CHAMBER BASE 2 135
A.21 SEDIMENTATION CHAMBER BASE 3 136

A.22 SEDIMENTATION CHAMBER BASE 4 137
A.23 SEDIMENTATION CHAMBER OUTER WALL 138
A.24 COAGULATION TANK INNER WALL 139
A.25 COAGULATION TANK WATER WAY 1 140
A.26 COAGULATION TANK WATER WAY 2 141
A.27 SEDIMENTATION CHAMBER DIVIDER 142
A.28 SEDIMENTATION CHAMBER 2 OUTER WALL 143
A.29 MONITORING TANK FULL ASSEMBLY 144
A.30 MONITORING TANK WALL 1 145
A.32 MONITORING TANK WALL 3 147
A.33 MONITORING TANK WALL 4 148
A.34 MONITORING TANK BASE 149
APPENDIX B – ELECTRICAL SCHEMATIC 150
B.1 INFRA RED CIRCUIT SCHEMATIC 150
B.2 PHOTODIODE AMPLIFIER CIRCUIT SCHEMATIC 150
B.3 RELAY BOARD SCHEMATIC 151
B.4 pH AMPLIFIER CIRCUIT 151
APPENDIX C-DATASHEET 152
C.1 MA-16 152
C.2 ULN 2003 161
C.3 PHE 7352-15 166
APPENDIX D – WATER STANDARDS IN INDONESIA 167
D.1 WATER CLASSIFICATION 167
D.2 INDUSTRIAL WASTE WATER STANDARDS 171
D.3 DOMESTIC WASTEWATER STANDARDS 172
D.4 HOSPITAL WASTEWATER STANDARDS 173
D.5 CLEAN WATER 174
D.6 BOTTLED DRINK WATER STANDARDS 175
APPENDIX E – PROGRAM SOURCE CODE 176
E.1 MICROCONTROLLER AVR PROGRAM 176
E.2 Qt mainwindow.h 183
E.3 Qt mainwindow.cpp 184
APPENDIX F – BILL OF MATERIAL 201
CURRICULUM VITAE 202

SWISS GERMAN UNIVERSITY