COUPLE DESIGN AND OPTIMIZATION OF HIGH TEMPERATURE NUCLEAR REACTOR AND HYDROGEN PRODUCTION SYSTEM

By

Christoforus Krisna
11604017

BACHELOR'S DEGREE
in

CHEMICAL ENGINEERING - SUSTAINABLE ENERGY AND ENVIRONMENT
FACULTY OF LIFE SCIENCES AND TECHNOLOGY

SWISS GERMAN UNIVERSITY
The Prominence Tower
Jalan Jalur Sutera Barat No.15 Alam Sutera
Tangerang, Banten 15143 - Indonesia

July 2020

Revision after Thesis Defense on 6th of July 2020

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, nor material which to a substantial extent has been accepted for the award of any other degree or diploma at any educational institution, except where due acknowledgement is made in the thesis.

Christoforus Krisna Kuma

Student Date

Dr.-Ing. Diah Indriani Widiputri S. T., M.Sc.

Thesis Advisor Date

Dr. Eng. Topan Setiadipura, M.Si, M.Eng

Thesis Co - Advisor Date

Dr. Dipl.-Ing. Samuel P. Kusumocahyo

Dean of Faculty of Life Sciences and Technology Date

SGU ®
SWISS GERMAN UNIVERSITY

ABSTRACT

COUPLE DESIGN AND OPTIMIZATION OF HIGH TEMPERATURE NUCLEAR REACTOR AND HYDROGEN PRODUCTION SYSTEM

By

Christoforus Krisna Kuma

Dr.-Ing.Diah Indriani Widiputri S.T, M.Sc.
Dr. Eng. Topan Setiadipura, M.Si, M.Eng

SWISS GERMAN UNIVERSITY

Nuclear energy is a type of renewable energy. Nuclear energy is using Uranium as fuel for producing heat, then the heat will generate steam and the steam will generates turbine to produce electricity. In Indonesia, nuclear power is still developing. Indonesian Nuclear Agency called Badan Tenaga Atom Nasional or BATAN is used nuclear energy to generate electricity, or for other study purposes, such as mutation of crop's gen by radiation and the topaz formation by radiation. Normally Nuclear energy is used for generates electricity however, the power produced can be utilize for other purposes such as coupling system with other plant. In this study the couple system between nuclear reactor and hydrogen generation plant will carried out. MgCl cycle is used for hydrogen generation plant, since $MgCl_2$ is more economical than fossil fuel and the energy required is for producing 1 gram of hydrogen is 34KJ, this is less than steam methane reforming method. In order to increase the hydrogen production, the study of $MgCl_2$ will be shown in this thesis and the economical evaluation of hydrogen is approximately 1.48 USD for producing 1 Kg of hydrogen. The study of economical evaluation of hydrogen by using HEEP application will also carried out in this thesis.

keywords: Nuclear Energy, Nuclear Power, Uranium, Couple Design, Hydrogen Generation, MgCl Cyle, Hydrolsysis

© Copyright 2020
by Christoforus Krisna Kuma
All rights reserved

SWISS GERMAN UNIVERSITY

DEDICATION

I dedicate this thesis work to myself, my adviser, my friends in the university,
and all who always support me in every situations,
especially to my family.

SWISS GERMAN UNIVERSITY

ACKNOWLEDGEMENT

First of all, I would like to thank God for His blessing in my entire life, so that I could finish my study in Swiss German University. Without His grace, I would not be able to finish my thesis, my study, as well as all things that happened during my university life.

My deepest gratitude also goes to my adviser, Mrs.Diah who always encourage and support me in every situation, and guide me patiently, and who always guide me to find way out whenever I stuck in the process. And also gratitude to my Co-Adviser, Mr. Topan Setiadipura who always teach and support me for study about this thesis.

I would also like to thanks to BATAN that gives me opportunity for doing research. And for other supervisors and other workers who always giving me support and encourage me to finish the research.

I would like to express my thankfulness to other lecturers who always taught me patiently. And I would like also express my thankfulness to my colleagues, especially Daniel Pradipta and Faikar Achmad Lutfi who always help and support me, and all friends whom I cannot mention one by one, for all the togetherness, advice, happiness, support and encouragement.

The final word of my appreciation goes to my beloved family for support me, encourage me, and help me during this research. Thank you for encouraging me throughout the process and helping me to see my goal in life.

SGU ®
SWISS GERMAN UNIVERSITY

TABLE OF CONTENTS

STATEMENT BY THE AUTHOR 2
ABSTRACT 3
DEDICATION 5
ACKNOWLEDGEMENT 6
TABLE OF CONTENTS. 7
LIST OF FIGURES. 9
LIST OF TABLES. 10
1 CHAPTER I – INTRODUCTION. 12
1.1 Background 12
1.2 Research Objectives 13
1.3 Significance of Study 13
1.4 Research Questions 13
2 CHAPTER II – LITERATURE REVIEW 14
2.1 Nuclear Energy 14
2.1.1 Utilization Of Nuclear Energy 15
2.1.2 Nuclear Power plant 18
2.2 Type of Nuclear Reactor 20
2.1.3 High Temperature Gas Reactor (HTGR). 20
2.1.4 Light Water Reactor (LWR) 21
2.1.5 Heavy Water Reactor (HWR) 22
2.1.6 Small co-generation nuclear power plant 22
2.2 Hydrogen. 23
2.3 Hydrogen Demand 25
2.4 Hydrogen Production 26
2.4.1 $MgCl_2$ Cycle 26
2.4.2 Gasification of Biomass 27
2.4.3 Dark Fermentation 28
2.5 Type Of Steam Turbine 28
2.5.1 The classification of steam turbine by the number of pressure stages. 28
2.5.2 The classification of steam turbine by the type of steam flow 29
2.5.3 The classification of steam turbine by the heat drop process 30
2.6 Uranium 32
3 CHAPTER III - RESEARCH METHODS 36
3.1 Venue and Time 36
3.2 Material and Equipment 36
3.3 Design of research 36
3.4 Experimental Procedure 37
3.4.1 Designing Reactor 37
3.4.2 Hydrogen Economic Evaluation 38
4 CHAPTER IV - RESULTS AND DISCUSSIONS 43
4.1 Literature Study 44
4.1.1 Comparison between different types of nuclear power plant 44
4.1.2. Comparison between each type of steam turbine 46
4.1.3. Study of each Hydrogen Production Method 46
4.1.4. Design of Hydrogen generation plant 47
4.2 Design of reactor using PEBBED6. 48

4.2.1. User Interface of PEBBED6. 48
4.2.2. PEBBED6 algorithm 49
4.2.3. PEBBED6 Input 52
4.2.4. Ouput of PEBBED6. 55
4.3. Couple Design between Nuclear reactor and Hydrogen generation plant 58
4.4 Energy Balance Calculation for Couple Design. 59
4.4.1 Hydrolysis of $MgCl_2$ Reaction Analysis 59
4.4.2 Chlorination of MgO Reaction Analysis 61
4.5 Energy Balance Analysis for every equipments. 62
4.6. Economic Evaluation by using HEEP application 64
4.6.1 User Interface of HEEP 64
4.4.2 Chlorination of MgO Reaction Analysis 65
4.6.3 HEEP Output Analysis 66
4.7 Evaluation of the result of coupling system between HTGR and Hydrogen Generation Plant 67
5 CHAPTER 5 – CONCLUSION AND RECOMMENDATION 69
5.1 Conclusion 69
5.2 Recommendation 69
REFERENCES 70

SWISS GERMAN UNIVERSITY

LIST OF FIGURES

Figure 2.1 Nuclear Power Production Statistic 14
Figure 2.2 Fission Reaction 15
Figure 2.3 Sterilization by irradiation 16
Figure 2.4 Sterilization of medical equipment by radiation. 17
Figure 2.5 Sea Water Desalination System. 18
Figure 2.6 Fuel Rods 18
Figure 2.7 Nuclear Reactor Illustration. 19
Figure 2.8 Reactor Core 19
Figure 2.9 HTGR Diagram. 20
Figure 2.10 LWR Diagram. 21
Figure 2.11 HWR Diagram 22
Figure 2.12 Nuclear Power Plant Diagram 22
Figure 2.13 TRISO Layers 24
Figure 2.14 World Consumption of hydrogen in 2017 26
Figure 2.15 $MgCl_2$ Cycle 26
Figure 2.16 Gasification of Biomass processes 28
Figure 2.17 Single Stage Turbine 29
Figure 2.18 Multistage Turbine 29
Figure 2.19 Steam Turbine Flow Directions 30
Figure 2.20 Condensing Steam Turbine 30
Figure 2.21 Back Pressure Drop Steam Turbine 31
Figure 2.22 Uranium Isotope's. 32
Figure 2.23 Open Pit Illustration 33
Figure 2.24 Underground Illustration 33
Figure 2.25 In Situ Recovery Illustration. 34
Figure 2.26 Enrichment Process 35
Figure 2.27 Pelletized Uranium 35
Figure 3.1 Design of literature study 36
Figure 3.2 Design of Research 37
Figure 3.3 Design of Research 38
Figure 3.4 Card and Input in PEBBED6 38
Figure 3.5 HEEP 39

SWISS GERMAN UNIVERSITY

Figure 3.6 HEEP input parameters *40*
Figure 3.7 Input Parameters. *41*
Figure 4.1 Hydrogen Generation Plant flow *48*
Figure 4.2 User Interface of PEBBED6. ..... *49*
Figure 4.3 PEBBED6 manual book *49*
Figure 4.4 PEBBED6 manual book *50*
Figure 4.5 PEBBED6 input information. *51*
Figure 4.6 PEBBED6 input in notepad *51*
Figure 4.7 PEBBED6 output in notepad *52*
Figure 4.8 User Interface of Input in PEBBED6 ..... *52*
Figure 4.9 Output in PEBBED 6. ..... *56*
Figure 4.10 Couple Design of Nuclear reactor and Hydrogen Generation Plant *58*
Figure 4.11 $MgCl_2$ Born-Haber Cycle *60*
Figure 4.12 MgO Born-Haber Cycle *61*
Figure 4.13 Effect of Reactor Temperature of MgOHCl production. *63*
Figure 4.14 User Interface of HEEP application. *65*

SWISS GERMAN UNIVERSITY

LIST OF TABLES

Table 2.1 Reactor specifications 24
Table 3.1 Finance Details Input 40
Table 3.2 Nuclear Power Plant Input Parameters. 41
Table 3.3 Hydrogen Generation Plant Input Parameters. 42
Table 3.4 Hydrogen Storage Plant Input Parameters. 42
Table 4.1 Pros and Cons of every type of reactors 45
Table 4.2 Information of every card input for PEBBED 6. 53
Table 4.3 Input data of PEBBED 6 54
Table 4.4 Axial and Radial Trials on PEBBED 6 55
Table 4.5 Output data of Temperature on PEBBED 6. 56
Table 4.6 Enthalpies of every reactions 60
Table 4.7 Enthalpies of every reaction 63
Table 4.8 Enthalpies of every equipment 63
Table 4.9 First Input of Nuclear Power Plant in HEEP application 65
Table 4.10 Second Input of Nuclear Power Plant in HEEP application 66
Table 4.11 Input parameters of Hydrogen Generation Plant in HEEP application 66
Table 4.12 First Output and result of HEEP application 67
Table 4.13 Second Output and result of HEEP application 67

SWISS GERMAN UNIVERSITY