

POTENTIAL OF ORGANIC RANKINE CYCLE BASED HEAT RECOVERY SYSTEMS FOR POWER GENERATION

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Thesis submitted in partial fulfillment of the requirements for the degree Master
of Engineering

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June 2015

DECLARATION

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ABSTRACT

Due to intense fuel dependency on energy production in the world, cost of energy has a greater bearing on the prices of fossil fuels. Most of the countries in the world are suffering due to this and Sri Lanka is no exception. It is in this context promotion of optimize the usage of thermal power generation, is so vital to the country. Even though fossil fuel base power generation plays a greater role as a source of primary energy in the country, major portion wasted to environment. WHR systems have been already introduced, but most of them are not performing effectively and efficiently. On other hand, novel systems and technologies required to investigate, to recovery most of the wasted heat of thermal plant while increasing the system efficiency and reducing the fuel cost. Conceptual thermodynamic cycles such as Trilateral Flash cycle, Organic Rankine cycle, Kalian cycle and Gaswami cycle, can be successfully incorporate for WHR applications. Hence, purpose of this research was to assess the amount of waste heat generated by thermal plants in the country while discussing the possible technologies that can be introduce for heat recovery. Further, discuss about selection of most suitable option and carryout thermo-economic analysis as a case study.

Fluid selection and system optimisation based on heat source temperature are two most critical aspect of Organic Rankine Cycle. Eleven fluids were investigated to optimize the work output by varying the evaporator temperature and varying the expander pressure ratio with theoretical model. In evaporator analysis, Heptane, Pentane and Decane shows favourable results in terms of work outputs while, in terms of efficiency, Decane and Heptane are better. Further it is recommended to use fluid Pentane, when source temperatures of WHR lies between 45 – 190 °C, while fluid Heptane is recommended when source temperature between 190 – 260 °C. Fluid Decane is recommended when temperature between 260 – 340 °C. Respective monographs were developed where one point on the graph can denote approximate work output, efficiency, pressure, temperature, etc. Based on expander analysis, Decane, Heptane and Toluene fluids have shown higher work outputs while, in terms of efficiency, Decane is better. In expander selection, when inlet/outlet pressure ratios are less than 10, fluid Decane is recommended. Further, when ratios are in between 10 – 13 and 13 – 20, fluid Heptane and fluid Toluene are recommended respectively. Refer to these 03 fluids, monographs were developed accordingly.

Refer to optimum working regions of temperature analysis; fluids were selected for economic evaluation. Waste heat recovery opportunities were selected from existing thermal plants for the case study and electric outputs were obtained for each plant, based upon selected fluids from theoretical model. Then maximum work out of each opportunity was selected for further economic evaluation under 07 different scenarios. Possible future economic situations of the country were predicted under those scenarios and carryout NPV calculations for each, to evaluate the investment feasibility. Scenario 2, 3 and 7 are the most possible situations of the country in future and for those conditions, WH opportunities at Supugaskanda, Lakvijaya, Keravalapitiya and Kelanithissa are most feasible to recover waste heat with ORC system.

ACKNOWLEDGEMENTS

This thesis was prepared as a part of my MEng program offered by the University of Moratuwa, Sri Lanka. During the course of this research there were many individuals who supported me in various ways to complete this work successfully.

In first place, this thesis would not have been possible unless continuous guidance, expertise and comments of my supervisor, Dr. Chathura Ranasinghe, Senior Lecturer of Moratuwa University. Form the day I conceived this research idea, he made sure that this work moved gradually towards the culmination smoothly. Further, I would like to express my sincere gratitude to Dr. H.K.G. Punchihewa and Dr. M.M.I.D. Manthilake of University of Moratuwa, on their valuable comments when I most required.

Most difficult part of this exercise was the collection of data related to waste heat energy of each thermal power plant in the country. My special thanks in this regard should go to my fellow engineers who have supported in data collection in various thermal power plants.

The biggest challenge I faced during this research was to find time for this and meeting the targets. I am sure if not for my wife, Nadeeka De Silva, my new born son Dihas and my mother I.D. Priyangani, I could not have completed this research on time. Hence, my gratitude should go to my beloved family members for the sacrifices they made during this research.

TABLE OF CONTENTS

Declaration	i
Abstract	ii
Acknowledgement	iii
Table of Contents	iv
List of Figures	vi
List of Tables	ix
List of Abbreviations	xi
List of Appendices	xii
1.0 Introduction	1
2.0 Thermal Power Generation	4
2.1 Present Status	4
2.2 Thermal Plants in Sri Lanka	7
2.3 Power Generation and Efficiencies of Thermal Plants	8
2.4 Thermodynamic Cycles	12
2.5 Plant Configurations	14
  University of Moratuwa, Sri Lanka. Electronic Theses & Dissertations www.lib.mrt.ac.lk	
3.0 Waste Heat Recovery	15
3.1 Waste Heat Definitions and Classifications	15
3.2 WH Classification Based on Temperature	16
3.3 Waste Heat Recovery Classification	19
3.4 Low Grade Heat Recovery Cycles	21
3.4.1 Organic Rankine Cycle (ORC)	21
3.4.2 Kalina Cycle	22
3.4.3 Gaswami Cycle	24
3.4.4 Trilateral Flash Cycle	26
3.5 Selection of Thermodynamic Cycle	28
4.0 Organic Rankine Cycle	30
4.1 Properties of Working Fluid	30
4.2 Fluid Classification Based on T-S diagram	31
4.3 ORC Configuration	33
4.4 System Modeling	35

5.0 Results and Discussion	38
5.1 Selected Fluids	38
5.2 Fluid Analysis	40
5.2.1 Analysis on Evaporator Temperature Variation	41
5.2.2 Key Findings in Temperature Analysis	51
5.2.3 Analysis of Pressure Ratio Variation on Expander	54
5.2.4 Key Findings in Pressure Ratio Analysis	64
5.3 Development of Monographs	66
5.3.1 Temperature Based Monographs	66
5.3.2 Pressure Ratio Based Monographs	67
6.0 Case Study	74
6.1 Selection of Waste Heat Opportunities	74
6.2 Performance Evaluation of Selected Fluids	75
7.0 Economic Analysis	80
7.1 Investment Cost on ORC	80
7.2 Net Present Value (NPV)	82
7.3 NPV Results	85
8.0 Conclusions	87
University of Moratuwa, Sri Lanka. Electronic Theses & Dissertations..... www.lib.mrt.ac.lk	
List of Reference	91
Appendix A: Details on waste heat in thermal power plants	94
Appendix B: ORC performance analysis with evaporator temperature variation	99
Appendix C: ORC performance analysis with expander pressure ratio variation	121
Appendix D: Work output calculations for case study	143
Appendix E: Net Positive Value calculations	145

LIST OF FIGURES

Chapter 01		Page
Figure 1.1	Electricity generation mix of Sri Lanka in the years 2012 and 2013	1
Chapter 02		
Figure 2.1	Hydro/Thermal/Non-conventional energy share in the national grid	4
Figure 2.2	Total imports Vs petroleum imports over the last 05 years	5
Figure 2.3	Total exports Vs petroleum imports over the last 05 years	6
Figure 2.4	Graph of average selling price of electricity	6
Figure 2.5	Thermodynamic cycles, according to their operating temp. range	12
Chapter 03		
Figure 3.1	Waste heat source classification based on temperature	16
Figure 3.2	Waste heat recovery method classification	19
Figure 3.3	Basic configuration of Kalina cycle	23
Figure 3.4	Basic configuration of Goswami cycle	25
Figure 3.5	Layout of Trilateral Flash cycle	26
Figure 3.6	T-S diagram of Trilateral Flash cycle	27
Chapter 04		
Figure 4.1	Saturated vapour line for Dry, Isentropic and Wet Fluids	31
Figure 4.2	Basic configuration of ORC system	33
Figure 4.3	Basic T-s diagram for ORC system	34
Chapter 05		
Figure 5.1	Input and expander work variation with different evaporator temperature for Decane	42
Figure 5.2	Work input and efficiency variation with different evaporator temperature for Decane	43
Figure 5.3	Input and expander work variation with different evaporator temperature for Decane	43
Figure 5.4	Work output variation with different evaporator temperatures	44

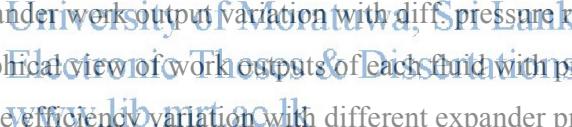
Figure 5.5	Graphical view of maximum possible work outputs of each fluid with temperature	45
Figure 5.6	Cycle efficiency variation with different evaporator temperatures	46
Figure 5.7	Graphical view of maximum possible efficiencies of each fluid with temperature	47
Figure 5.8	Maximum work output region for each fluid	50
Figure 5.9	Evaporator temperature range for maximum work output region	50
Figure 5.10	Efficiency variations of pressure and temperature of fluid Decane	52
Figure 5.11	Expander output variation with pressure and temperature of fluid Decane	53
Figure 5.12	Input and expander work variation with different pressure ratios, Decane	55
Figure 5.13	Input and eff. variation with diff. expander pressure ratios, Decane	56
Figure 5.14	Input and expander work variation with different pressure ratios, Decane	56
Figure 5.15	 University of Moratuwa, Sri Lanka Expander output variation with different pressure ratios	57
Figure 5.16	Graphical view of work outputs of each fluid with pressure	58
Figure 5.17	 Cycle efficiency variation with different expander pressure ratios	59
Figure 5.18	Graphical view of efficiencies of each fluid with pressure	60
Figure 5.19	Maximum work output range with expander pressure variation	62
Figure 5.20	Expander pressure range for maximum work output region	63
Figure 5.21	Efficiency variation with pressure and temperature of fluid Decane	64
Figure 5.22	Expander output variation with pressure and temperature of fluid Decane	65
Figure 5.23	Different temperature curves with iso-efficiency lines against work output for fluid Pentane	68
Figure 5.24	Different temperature curves with iso-efficiency lines against work output for fluid Heptane	69
Figure 5.25	Different temperature curves with iso-efficiency lines against work output for fluid Decane	70
Figure 5.26	Different pressure ratio curves for expander with iso-efficiency lines against work output for fluid Decane	71

Figure 5.27	Different pressure ratio curves for expander with iso-efficiency lines against work output for fluid Heptane	72
Figure 5.28	Different pressure ratio curves for expander with iso-efficiency lines against work output for fluid Toluene	73

Chapter 06

Figure 6.1	Energy recovery at each opportunity by different fluids	78
Figure 6.2	Energy recovery at each opportunity by different fluids, except Keravalapitiya and Kelanithissa plants	78



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 Electronic Theses & Dissertations
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LIST OF TABLES

Chapter 02		Page
Table 2.1	CEB owned thermal power plants and respective power generations 2013	7
Table 2.2	IPP owned thermal power plants and respective generations 2013	8
Table 2.3	Generation and efficiencies of SPS	9
Table 2.4	Generation efficiencies of KPS	9
Table 2.5	Combined cycle power plant- Kelanithissa	10
Table 2.6	AES Kelanithissa Plant	10
Table 2.7	West coast power plant	11
Table 2.8	Summary of exhaust gas temperature and volumes of CEB thermal plants	11
Table 2.9	Thermodynamic cycle combination matrix	13
Table 2.10	Common configurations of thermodynamic cycles	14
Chapter 03	 University of Moratuwa, Sri Lanka. Electronic Theses & Dissertations www.lib.mrt.ac.lk	
Table 3.1	Classification of waste heat by temperature	18
Table 3.2	Kalina cycle case-studies	24
Table 3.3	Comparison of TFC, ORC and Kalina cycle	28
Chapter 05		
Table 5.1	Physical, safety and environmental data of selected fluids	39
Table 5.2	Details of maximum work output point for each fluid	48
Table 5.3	Details of maximum output and efficiency ranges of each fluid	49
Table 5.4	Details on maximum work output point in each fluid	61
Table 5.5	Details of max. output range and efficiency ranges of each fluid	61
Chapter 06		
Table 6.1	Waste heat of thermal plants and recommended fluids	74
Table 6.2	Sapugaskanda plant exhausts heat recovery	76
Table 6.3	Lakvijaya plant exhausts heat recovery	76

Table 6.4	Lakvijaya plant blow down heat recovery	76
Table 6.5	Jaffna plant exhausts heat recovery	76
Table 6.6	Keravalapitiya plant exhausts heat recovery	77
Table 6.7	Kelanithissa GT plant exhausts heat recovery	77
Table 6.8	Maximum electrical output and related fluid for each opportunity	79

Chapter 07

Table 7.1	Reputed ORC manufacturers and their plant details	81
Table 7.2	Estimated capital investment for heat recovery opportunities	83
Table 7.3	Different scenarios that NPV calculations done for project feasibility	84
Table 7.4	Plant running hours and interest rate for scenario 7	84
Table 7.5	Nat Positive Values for different WHR opportunities	85
Table 7.6	Summery of feasibility of the investments	86



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LIST OF ABBREVIATIONS

CEB – Ceylon Electricity Board	\dot{W}_{exp}	- Expander work
NRE – Non-Renewable Energy	\dot{m}	- Fluid mass flow rate
WHR – Waste Heat Recovery	h	- Specific enthalpy
IPP – Independent Power Producers	η_{is}	- Expander isentropic efficiency
HSFO – High Sulfur Fuel Oil	$\dot{W}_{\text{exp.is}}$	- Expander isentropic work
LSFO – Low Sulfur Fuel Oil	Q_{evap}	- Evaporator heat energy addition
SPS – Sapugaskanda Power Station	$\dot{W}_{\text{pump.is}}$	- Pump isentropic work
KPS – Kelanithissa Power Station	P	- Pressure
GT – Gas Turbine	ρ_{liquid}	- Fluid density
ST – Steam Turbine	\dot{W}_{pump}	University of Moratuwa, Sri Lanka Electronic Theses & Dissertations - Pump work
CCPP – Combined Cycle Power Plant	η_{pump}	- Pump efficiency
CCGT – Combined Cycle Gas Turbine	$\eta_{\text{pump.is}}$	- Pump isentropic efficiency
LPT – Low Pressure Turbine	η_{cycle}	- Cycle Efficiency
HPT – High Pressure Turbine	\dot{W}_{in}	- Work input
IPT – Intermediate Pressure Turbine	\dot{W}_{out}	- Work output
CHP – Combined Heat & Power	$Q_{\text{evap. max}}$	- Maximum available heat energy for evaporator
ORC – Organic Rankine Cycle		
TFC – Trilateral Flash Cycle	η_{evap}	- Evaporator efficiency
NPV – Net Positive Value	P_1/P_2	- Expander pressure ratio between inlet and outlet

LIST OF APPENDICES

Appendix	Description	Page
Appendix A	Details on waste heat in thermal power plants	93
Appendix B	ORC performance analysis with evaporator temperature variation	98
Appendix C	ORC performance analysis with expander pressure ratio variation	120
Appendix D	Work output calculations for case study	142
Appendix E	Net Positive Value calculations	144



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