

Dedicated to
My Family, Friends
and
Well Wishers
Who Supported and Endured Me



Tezpur University

CERTIFICATE

This is to certify that the thesis entitled “*Exergetic performance analysis of MHD (Magnetohydrodynamics) and MHD integrated gas turbine power plant*” submitted to the School of Engineering, Tezpur University in part fulfillment for the award of the degree of Doctor of Philosophy in Mechanical Engineering is a record of research work carried out by Mr. Prabin Haloi under my supervision and guidance.

All help received by him from various sources have been duly acknowledged. No part of this thesis has been submitted elsewhere for award of any other degree.

Date:

Supervisor

Place:

(Prof. Tapan Kr. Gogoi)

Declaration

I do hereby declare that the matter embodied in this thesis is the result of study and investigations carried out by me in the Department of Mechanical Engineering, Tezpur University, Tezpur, India under the guidance of Professor Tapan Kr. Gogoi, Professor, Department of Mechanical Engineering, Tezpur University.

In keeping with the general practice of reporting scientific observations, due acknowledgements have been made wherever the work described is based on the findings of other investigators.

Date:

Prabin Haloi

Place:

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(Prabin Haloi)

TABLE OF CONTENTS

<i>Contents</i>	<i>Page No.</i>
<i>Dedication</i>	ii
<i>Abstract</i>	iii-vii
<i>Certificate</i>	viii
<i>Declaration</i>	ix
<i>Acknowledgement</i>	x
<i>Table of Contents</i>	xi
<i>List of Chapters</i>	xii-xx
<i>List of Tables</i>	xxi-xxii
<i>List of Figures</i>	xxiii-xxiv
<i>Nomenclature</i>	xxv-xxix

LIST O F TABLES

<i>Table No.</i>	<i>Description</i>	<i>Page no.</i>
Table 3.1.	Determination of mass flow rates, HHV and thermal input	55
Table 3.2.	Computing nozzle exit Mach number	58
Table 3.3.	Computation of nozzle parameters	59
Table 3.4.	Determination of MHD system parameters	59
Table 4.1.	Determination of fuel-air ratio, HHV, LHV, chemical exergy and chemical exergy ratio	75
Table 4.2.	Mass flow rates, temperature and pressure of flow streams for the MHD plant	75
Table 4.3.	Energy and exergy rates of the flow streams of the MHD plant	76
Table 4.4.	Component-wise energy loss and exergy destruction rates of the MHD plant	77
Table 4.5.	Compressor power, generator power, net power output, thermal efficiency and exergetic efficiency of the MHD plant	78
Table 5.1.	Molar specific heats and specific molar enthalpies of dissociated MHD combustion product species (kJ/kmol) at the states 6 and 7	96
Table 5.2.	Molar specific heats and specific molar enthalpies of undissociated MHD combustion product species (kJ/kmol) at the states 6 and 7	96
Table 5.3.	Specific molar entropies of dissociated MHD combustion product species (kJ/kmol-K) at the states 6 and 7	97
Table 5.4.	Specific molar entropies of undissociated MHD combustion product species (kJ/kmol-K) at the states 6 and 7	97
Table 5.5.	Mass flow rate, temperature and pressure at various state points of the MHD plant	104
Table 5.6.	Energy and exergy rates at various state points of the MHD plant in MW	105
Table 5.7.	Component-wise exergy flow rate, exergy destruction rate and exergetic efficiencies of the MHD plant	106
Table 5.8.	Mass flow rate, temperature, pressure, energy and exergy rates at the various state points of the GT plant	107
Table 5.9.	Component-wise exergy flow rate, exergy destruction rate and exergetic efficiencies of the GT plant	108

Table 5.10.	Comparison of exergy based results with molecular and ionized combustion products	109
Table 6.1.	Percentage composition of the constituents of air (<i>assumed</i>) and combustion products (<i>actual</i>)	131
Table 6.2.	Mass fractions of ionic species formed during partial ionization	133
Table 6.3.	Energy and exergy balances for the components of the MHD	135
Table 6.4.	Assumptions of hypothetical, actual and unavoidable conditions	139
Table 6.5.	Mass flow rate, state properties, energy and exergy rates at various states of the standalone MHD power generation system	140
Table 6.6.	Results of standard exergy analysis for the units of the MHD system	142
Table 6.7.	Splitting of exergy destruction in the j th unit into its main portions	143
Table 6.8.	Exogenous exergy destruction in the j th unit of the MHD system	144
Table 6.9.	Classifying exergy destruction in the j th unit into the sub-portions	145
Table 6.10.	Comparison of mass flow rates and exergy rates between Ref. and present study	150
Table 6.11.	Results of validation of the present study	150

LIST OF FIGURES

<i>Figure No.</i>	<i>Figure Name</i>	<i>Page No.</i>
Fig. 1.1.	Linear (continuous) generator	11
Fig. 1.2.	Segmented Faraday generator	11
Fig. 1.3.	Diagonal type MHD generator	11
Fig. 1.4.	Hall type MHD generator	11
Fig. 1.5.	Disk type MHD generator	12
Fig. 2.1.	Coal-fired MHD-steam turbine combined cycle with O ₂ enrichment of MHD air	34
Fig. 2.2.	Three-level open-cycle MHD combined system	34
Fig. 2.3.	Three-level closed-cycle MHD combined system	35
Fig. 2.4.	MHD-GT-ST combined cycle with tail gasification	35
Fig. 3.1.	Schematic of a typical MHD power plant	53
Fig. 3.2.	Variation in nozzle exit flow Mach number with area ratio	60
Fig. 3.3.	Variation in nozzle exit temperature in <i>K</i> with change in exit Mach number	61
Fig. 3.4.	Variation in nozzle exit gas velocity with Mach number	61
Fig. 3.5.	Variation in maximum power density with nozzle area ratio	62
Fig. 3.6.	Variation in maximum voltage with Mach number	63
Fig. 4.1.	Schematic of the MHD power generation system	70
Fig. 4.2.	Equipment's thermal efficiency vs rate of energy loss of the MHD plant	79
Fig. 4.3.	Equipment's exergy efficiency vs rate of exergy destruction of the MHD plant	79
Fig. 5.1.	Schematic of the MHD gas-turbine power plant	91
Fig. 5.2.	Station-wise energy rates of the gas turbine in <i>MW</i>	111
Fig. 5.3.	Station-wise exergy rates of the gas turbine in <i>MW</i>	111
Fig. 5.4.	Station wise exergy destruction rates of the gas turbine in <i>MW</i> .	113
Fig. 6.1.	Schematic of stand-alone MHD power plant	128
Fig. 6.2.	Division of exergy destructions inside the <i>j</i> th unit of the system	137
Fig. 6.3.	Value of exergy destruction in the <i>j</i> th unit of the MHD system	146

Fig. 6.4.	Comparing endogenous exergy destruction rate in the j th unit of the MHD system in MW	147
Fig. 6.5.	Percentage comparison of the endogenous exergy destruction in the j th unit of the MHD system	148
Fig. 6.6.	Distribution of overall avoidable exergy destruction rate into endogenous and exogenous portions of the MHD system in MW	148
Fig. 6.7.	Distribution of overall unavoidable exergy destruction rate into endogenous and exogenous portions of the MHD system in MW	149

Nomenclature

A_e	Nozzle exit area (m ²)
A^*	Nozzle throat area (m ²)
\bar{c}_p	Molar specific heat (kJ kmol ⁻¹ K ⁻¹)
\dot{E}	Rate of energy transfer (MW)
$\Delta\bar{g}^0$	Standard Gibbs free energy change (kJ kmol ⁻¹)
$\Delta_f\bar{g}^0$	Standard Gibbs energy of formation (kJ kmol ⁻¹)
h	Plank's constant (J-sec)
\bar{h}	Molar specific enthalpy (kJ kmol ⁻¹)
\bar{h}_f^0	Molar specific enthalpy of formation (kJ kmol ⁻¹)
H_p	Enthalpy of products (kJ)
H_r	Enthalpy of reactants (kJ)
M^*	Mach number at throat
\dot{m}_a	Mass flow rate of air (kg s ⁻¹)
M_a	Molecular mass of air (kg kmol ⁻¹)
M_e	Nozzle exit Mach number
\dot{m}_f	Mass flow rate of fuel (kg s ⁻¹)
M_f	Molecular mass of fuel (kg kmol ⁻¹)
\dot{m}_{plasma}	Mass flow rate of plasma (kg s ⁻¹)
\dot{m}_{seed}	Mass flow rate of seeding material (kg s ⁻¹)

p_e	Exit pressure (bar)
p_0	Stagnation pressure (bar)
\dot{Q}_{th}	Rate of thermal heat input (MW)
R_u	Universal gas constant (8.314 kJ kmol ⁻¹ K ⁻¹)
\bar{s}	Absolute molar entropy (kJ kmol ⁻¹ K ⁻¹)
\bar{s}	Molar specific entropy (kJ kmol ⁻¹ K ⁻¹)
\bar{s}^0	Standard molar specific entropy (kJ kmol ⁻¹ K ⁻¹)
T_{adia}	Adiabatic flame temperature (K)
T_e	Nozzle exit temperature (K)
V_e	Nozzle exit velocity (m s ⁻¹)
\dot{w}_{AC}	Rate of air compressor work (MW)
\dot{W}_{cv}	Work done rate of the control volume (MW)
\dot{w}_e	Rate of electrical work output of the generator (MW)
ϕ_{dry}	Ratio of chemical exergy to net calorific value of dry coal

Greek Letters and symbols

∇	Del operator
ϕ_B	Magnetic flux (Tesla)
$\rho_{n,e}$	Electron number density (cm ⁻³)
ω_s	Statistical weight (atoms/electrons/ions per cubic centimeter)
σ	Electrical conductivity (Siemens/m)
Σ	summation

κ Boltzmann constant (J K⁻¹)

Subscripts

a atoms

ACT actual

comb combustion

CV control volume

e electrons

f formation

F fuel

i ions

H hypothetical

\mathcal{H} heavy particles

L loss

min minimum

P product

tot total

y instantaneous

Abbreviation

AC Air Compressor

APH Air Preheater

CC Combustion Chamber

CCPP Combined Cycle Power plant

CV	Control Volume
DSU	Desulphurization Unit
EA	Excess Air
GEN	Generator
GT	Gas Turbine
GTCC	Gas Turbine Combined Cycle
HHV	Higher Heating Value
HPT	High Pressure Turbine
HRSG	Heat Recovery Steam Generator
ICE	Internal Combustion Engine
LES	Large Eddy Simulation
LHV	Lower Heating Value
LMMHD	Liquid Metal Magnetohydrodynamic
MHD	Magnetohydrodynamic
MHDCC	MHD Combustion Chamber
MHD-GT	MHD-Gas Turbine
MHD-GT-ST	MHD-Steam Turbine-Gas Turbine
MILD	Moderate or Intense Low oxygen Dilution
NCV	Net Calorific Value
ORC	Organic Rankine Cycle
OTSG	Once Through Steam Generator

PaSR	Partially Stirred Reactor
PERC	Pittsburgh Energy Research Center
SSSF	Steady State Steady Flow
SRU	Seed Recovery Unit
TIT	Turbine Inlet Temperature
