ENERGY AND EXERGY ANALYSIS OF MULTIPLE EXTRACTION CUM CONDENSING STEAM TURBINE

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Abstract - The energy supplied to the demand narrowing down day by day around the world ,the growing demand of the power has made power plant of scientific interest, but most of the power plants are designed by the energetic performance criteria based on first law of thermodynamics .the real useful energy loss can not be identified by the first law of thermodynamics , because it does not differentiate between the quality and quantity of energy. Bagasse shares major chunk of fuels used to produce power in thermal power plants in India. Coal reservoirs are limited in quantity . The project on exergy analysis was undertaken on purna sahakari sakhar karkhana& thermal power plant project located in basmathnagar dist. hingoli, Maharashtra. The capacity of the plant is 19MW.

Energy analysis presents only quantities results while exergy analysis presents qualitative results about actual energy consumption the main objective is to analyze the system components separately and to identify and quantify sites having largest energy and exergy efficiency losses it also presents major losses of available energy at superheater , boiler and turbine section exergy destruction and energy loss consumption charts are drawn for different components . The results are tabulated and graphs are plotted ho show correlation between various parameters this project would also throw light on the scope for further research and recommendations for improvement in the further existing plant.

Key Words: **Energy , Exergy , Efficiency, Energy losses Exergy losses**

1. INTRODUCTION

Coal reservoirs are limited in quantity. Baggase shares major chunk of fuels used to produce power in thermal power plants in India. Steam power plants supply 57 % of total power demand in India. Baggase is the major source of energy in these power plants. The conversion efficiency from coal to electricity in steam power plants is low and combustion of coal has heavy negative impact on environment . Efficiency enhancement of baggase to electric power generation is major challenge against steam power plants. Thus, inefficient use of bagagase not only wastes resources but creates environmental pollution issues such as CO2, SO2 and NOx emissions.

Energy conservation study is many times focused on energy efficiency. The first law of thermodynamics is used to analyze the energy utilization. First law analysis doesn't use the quality aspect of energy. Exergy is the consequent of second law of thermodynamics. It is a property that enables us to determine the useful work potential in a given amount of energy at reference environmental state. A thorough understanding of exergy can provide insights into the efficiency, environmental impact and sustainability of energy systems. Exergy analysis is now widely used in design, simulation and performance evaluation of thermal and thermo-chemical systems. Cogeneration turbine systems, which produce heat at useful temperatures at the expense of reduced electrical power, have higher efficiencies than conventional steam turbine systems. The correct merit of cogeneration systems should be determined with the help of exergy analysis because energy analysis tends to overstate performance.

The Main aim of the study is to identify areas where energy losses are occurring and develop them for efficient and effective improvement in thermal power station. the main objective is to analyze the system components separately and to identify and quantify sites having largest energy and exergy efficiency losses it also presents major losses of available energy at superheater , boiler and turbine section exergy destruction and energy loss consumption charts are drawn for different components. The aim of the exergy analysis is to identify the magnitudes and the locations of real energy losses, in order to improve the existing systems, processes or components.

Plant Description:

The power plant has total installed power capacity of 19 MW in full load condition.

It is located 1200`-1900` above the sea level in the City of Hingoli.

Operating Conditions	Value
Mass flow rate of bagasse	10.41 kg/s
Superheated steam temp.	540^0C
Gross calorific value of bagasse	2100 kcal
Boiler pressure	$105kg/cm^2$
Steam pressure	$104kg/cm^2$
Ambient temp.	33^0C
Ambient pressure	$1.019120kg/cm^2$

1. ENERGY AND SECOND LAW EFFICIENCY (EXERGY EFFICIENCY) RELATIONS

The expressions of energy and exergy efficiencies for the extraction cum back pressure steam turbine (cogeneration) are based on the following definitions [6].

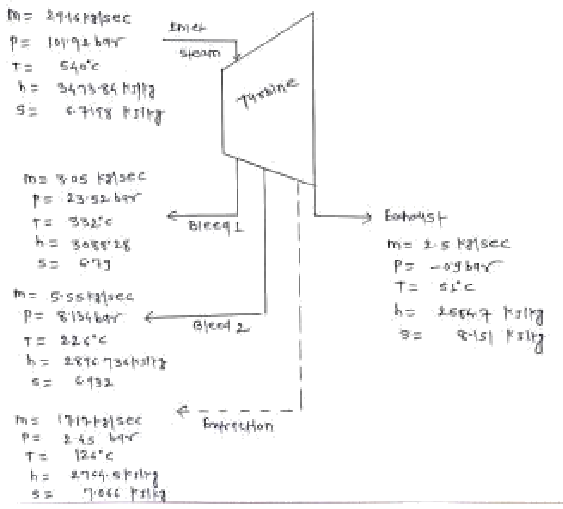
η I = (ActualPower Develop by Turbine Shaft) / (Ėin - Ėout) (1) η II = ΨPower / (Ψin- Ψout) = Ψ power / [ṁi (hi - Tosi) - (ṁo (ho - Toso)] (2)

1.1 THE REFERENCE ENVIRONMENT

Exergy is always evaluated with respect to a reference environment. The reference environment is in stable equilibrium, acts as an infinite system and is a sink or source for heat and materials. It experiences only internal reversible processes, in which its intensive properties (i.e. temperature T0, pressure P0) remains constant. In this analysis surrounding temperature and pressure are taken as T0=340C (307 K) and P0=101.325 kPa as based on weather and climate condition at Bhavnagar, Gujarat (India).

3. DATA OF STEAM TURBINE

Data for study is taken at 70 and 85 % MCR of Extraction cum Back Pressure Steam Turbine working at Nirma Ltd., Bhavnagar, Gujarat. The boiler of this power plant is fired by The boiler of this power plant is fired by bagasse blend having lignite (70%) + Indonesian bagasse (30%) and bagasse firing rate is 10.5 kg/s. The ultimate analysis of bagasse blend is as follows: C - 44.65 %, N - 1.21 %, H - 3.06 %, O - 10.8 %, S - 1.87 %, Ash - 10.5 %, Moisture - 27.78 % and GCV of bagasse is 4226 kcal/kg (17664.68 kJ/kg).



Assumptions:

1. There is no steam loss across steam turbine.
2. Gear box efficiency as per the manufacturer is 98.40 %
3. Generator efficiency as per the manufacturer is 98.03 %

High pressure extracted steam and low pressure exhaust steam from turbine is utilized in process heating of soda ash manufacturing.

4. STEAM TURBINE MAIN SPECIFICATIONS

Manufacturer: Hang Zhou Steam Turbine Co. Limited, China Model & Type: EHNG 50/40/50

Nominal Rating: 20600 kW Nominal Speed: 5022 rpm Normal first bled steam pressure: 35 bar

Normal first bled steam temperature: 3660C Normal exhaust steam pressure: 2.5 bar Normal

exhaust steam temperature: 1330C Number of stages: (1+23) / (Impulse + Reaction) Governor

manufacturer: Wood Ward Governor type: Electric & Hydraulic

Sr. No	Particular	Unit	Value at 70% MCR	Value at 85% MCR
1.	Main Steam Flow	Kg/s	20	24.791
2.	Main Steam Pressure	Kg/cm²	96	99.96
3.	Main Steam Temperature	⁰C	525	533
4.	Enthalpy of Inlet Steam	Kj/kg	3442.275	3456.473
5.	Entropy of Inlet Steam	Kj/kg K	6.704	6.698
6.	HP Extraction Flow	Kg/s	3.8	4.72
7.	HP Extraction Temperature	0C	216	221
8.	HP Extraction Pressure	Kg/cm²	6.3	7.35
9.	Enthalpy of HP Ext. Steam	Kj/kg	2884.228	2890.316
10.	Entropy of Inlet HP Ext. Steam	Kj/kg K	7.035	6.97
11.	LP Extraction Flow	Kg/s	12	15.11
12.	LP Extraction Temperature	0C	120	122
13.	LP Extraction Pressure	Kg/cm2	1.9	2.156
14.	Enthalpy of LP Exh. Steam	Kj/kg	2577.1	2581.1
15.	Entropy of Inlet LP Exh. Steam	Kj/kg/K	8.230	8.188
16.	Generator Power	KW	13875	17100

Analysis

A. ENERGY ANALYSIS FOR 70 % MCR

1. Energy input is equal to product of mass of steam into turbine and its enthalpy at entry .Ei = ṁs × h =18×3442.275
 = 61960.95 kj/sec

2. Energy output is sum of heat extracted and heat exhausted.

Ėo = (ṁblade2 × hblade2)+(ṁextr × hextr) + (mexha×hexha)
=(3.8×2884.228)+(12.5×2768.5)+(1.7×2577.1) = 50153.5544 kJ/s.

3. Work done is equal to the energy in steam at entry to turbine minus that at exit.

W.D = (Ėi – Ėo) =61960.95-50153.554 = 11807.396 kW.

4. Actual Power Develop by Turbine Shaft :

P = Generator Power x ɳ-1gearbox x ɳ-1generator =13350×(1/0.984)×(1/0.9804)=13839.71KW

5. Energy Efficiency (1st Law efficiency) of Turbine :

ɳ I = (Actual Power Develop by Turbine Shaft) / (Ėin – Ėout) = 13839 .71 / (61960.95-50153.544) = 74 %.

6. Heat Rate of Turbine :

HR = Net Heat Input / Turbine Power = (Ėi - Ėo) x 3600 s / 13839.715 = (61960.95 – 50153.5544) ×3600 / 13839.71 = 3071.35s kJ/kWh

B. EXERGY ANALYSIS FOR 70 % MCR

1. Exergy Input :

Ψin = ṁs (hs –To×Ss) = 18 ×(3442.275-307×6.704=24914.64kj/s

2. Exergy Out :

Ψout = ṁblade2 (hblade2-T o×Sblade2) + ṁextr (hextr-T o×Sextr) +mexha (hexha – T o×S exha) 3.8×(2884.225-

307×7.035)+12.5×(2768.5-307×7.144)+1.7×(2577.1-307×8.230) = 10030.0184 kJ/s.

3. Exergy Destruction in Turbine :

Ψdes= Ψin - Ψout - Ψpower = 24914.64-10030.0184-13839.71= 1044.91 kJ/s.

4. Exergy Efficiency (2nd Law efficiency) of Cogeneration Turbine :

ɳII = Ψpower / (Ψin - Ψout = 13839.71/24914.64-10030.0184 = 66.26 %

C. ENERGY ANALYSIS FOR 85 % MCR

1. Energy input is equal to product of mass of steam into turbine and its enthalpy at entry.

Ėi = ṁi x hi = 21.95×3456.473 = 75689.58 kJ/s.

2. Energy output is sum of heat extracted and heat exhausted.

Ėo = (ṁblade2 × hblade2) + (ṁextr × hextr) +(mexha×hexha) =

(4.72×2890.316)+(15.11×2768.5)+(2.125×2581.1) = 60959.164kJ/s.

3. Work done is equal to the energy in steam at entry to turbine minus that at exit.

W.D = Ė in - Ė out = 75689.58-60959.164 = 14730.416 kW.

4. Actual Power Develop by Turbine Shaft :

P = Generator power x ɳ-1gearbox x ɳ-

1generator =

16150×(1/0.984)×(1/0.9804) =16742.2

kW

5. Energy Efficiency (1st Law efficiency) of Turbine :

ɳ I = (Actual Power Develop by Turbine Shaft) / (Ėin – Ėout) = 16742.42/ (75689.58-60959.164) = 84.85 %.

6. Heat Rate of Turbine :

HR = Net Heat Input / Turbine Power = (Ėin – Ėout) x 3600 / 16742.42 =(75689.58-60959.164)×3600/167420.42 = 3167.37s kJ/kWh.

D. EXERGY ANALYSIS FOR 85 % MCR

1. Exergy Input :

Ψin = ṁs (hs-T o ×Ss) = 21.95(3456.473-307×6.698) = 30734.1046 kJ/s.

2. Exergy Out :

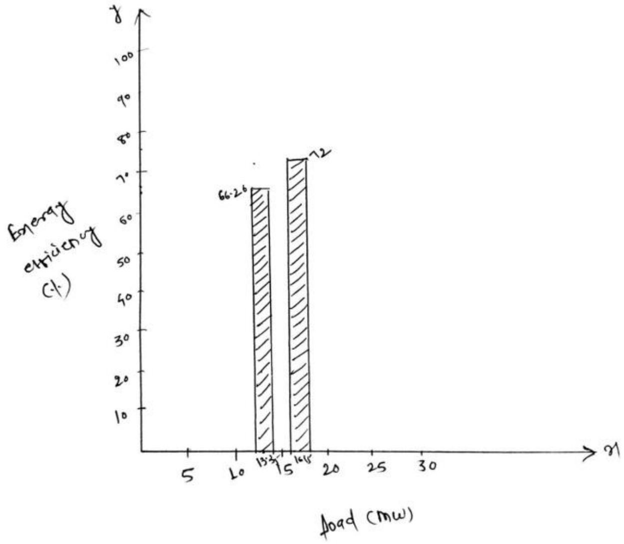
Ψout = ṁblade2 (hblade2 –T o×Ss) + ṁextr (hextr-T o×Sextr) +mexha(hextr –T o×Sexha)= 4.72×(2890.316-307×6.97)+15.11×(2768.5-307×7.11)+2.125×(2581.1-307×8.188) = 12541.27 kJ/s.

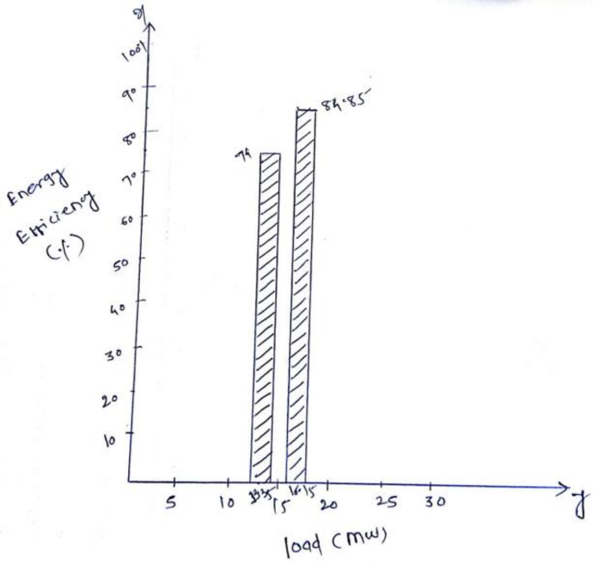
3. Exergy Destruction in Turbine :

Ψdes = Ψin – Ψout – Ψpower = 30734.1046-12541.27-16742.2=1450.6364 kJ/s.

4. Exergy Efficiency (2nd Law efficiency) of Cogeneration Turbine :

ηII = Ψpower / (Ψin - Ψout) = 16742.42/ (30734.10-12541.27) = 72%





Experimental Result show that as power load on steam turbine increases from 70% to 85% MCR

1.Turbines energy and exergy eff. Increases by 0.38% and 3.13%

2.Exergy destruction is increased by 438.34 kj/s due to steam turbine irregularities and lower exergy output of HP & LP steam.

3.The exergy efficiency is remarkably lower than energy efficiency in both the cases. This mainly due to thermal products, which is higher than electrical power, is delivered at lower temp.

4.There is an improvement observed in turbine heat rate by 17.01kj/kwhr.

5.Ash handling plant load is reduced by 41.47kg/day. This improves life of plant because ash is highly erosive in nature. It creates mech. Wear during handling.

6.Heat rate improvement leads to CO_2 emmission reduction by 26.89kg/hr & SO_2 reduction by 0.62kg/hr.

CONCLUSION

Turbine exergy efficiency is lower than its energyefficiency as utilization of heat is at lower temp. than inlet.

Turbine exergy loss is 5.74% & 10.85% at70% & 85% MCR.

When turbine MCR is increased from 70-85.

Thus it is more advantageous to run turbine at higher MCR.

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NOMENCLATURE

$\dot{E}i$ - Energy in [kJ/s], $\dot{E}out$ - Energy out [kJ/s],

Ψin - Exergy in [kJ/s], Ψout - Exergy out [kJ/s],

Ψdes - Exergy destruction [kJ/s] Ψpower –

Exergy of power [kJ/s], $\dot{m}$ - Mass flow rate [kg/s],

h - Specific enthalpy [kJ/kg], s - Specific entropy [kJ/kg K],

P -Turbine actual power [kW]

T0 - Atmospheric temperature [K],

P0 -Atmospheric pressure [kPa] , i - Inlet, o – Outlet,

ηI - Energy efficiency [%], ηII - Exergy efficiency [%],

HR- Heat rate [kJ/kWh], ext - steam extraction,

exh - steam exhaust, MCR - Maximum continuous rating,

GCV - Gross calorific value [kJ/kg], C – Carbon,

H – Hydrogen , O – Oxygen, N – Nitrogen,

S – Sulphur, SO2 - Sulphur dioxide, CO2 - Carbon dioxide,

NOx - Nitrogen oxide, HP – High pressure, LP – Low pressure.

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