INDIAN INSTITUTE OF TECHNOLOGY KANPUR

CHE221: CHEMICAL ENGINEERING THERMODYNAMICS

Laboratory Session 2 Report

Thermal Analysis and Entropy Change

Reported By: Anunay Minj
Roll No: 220183

Performed on: 19/01/2024
Report submitted on: 24/01/2024

1. Introduction

1.1 Background:

Central power plants play a crucial role in generating electricity for various applications. Understanding the thermodynamic efficiency of these plants is essential for optimizing their performance. Additionally, the quenching process, where a material is rapidly cooled, is a common practice in metallurgy and manufacturing. This report aims to analyze the heat discarded in a power plant and the entropy changes during the quenching process.

1.2 Objectives:

The primary objectives of this analysis are to determine the heat discarded in a central power plant and evaluate the entropy changes when a steel casting is quenched in oil.

2. Methodology:

Question 1: Heat Discarded in a Power Plant

2.1.1 Carnot Efficiency Calculation:

Calculate the Carnot efficiency using the formula:

$$Carnot\_eff = 1 - \frac{T_{Low}}{T_{High}}$$

2.1.2 Thermal Efficiency Calculation:

Determine the thermal efficiency as 70% of the Carnot efficiency:

$$Thermal\_eff = 0.7 \times Carnot\_eff$$

2.1.3 Maximum and Actual Work Calculation:

Calculate the maximum work (W_Max) and actual work (W_Actual) that can be obtained from the power plant.

2.1.4 Heat Discarded Calculation:

Heat discarded to the river is determined as the difference between maximum and actual work:

$$\boldsymbol{Q\_Discarded = W\_Max - W\_Actual}.$$

Question 2: Entropy Changes during Quenching Process

2.2.1 Temperature Conversion:

Initial temperatures of the steel casting and oil are converted from Celsius to Kelvin.

2.2.2 Intermediate Temperature Calculation:

The intermediate temperature is calculated using a weighted average of the initial temperatures of the casting and oil.

2.2.3 Entropy Change Calculation:

Entropy changes for the casting and oil are computed using the formula:

$$Entropy = mass \times specific\_heat \times \log\left(\frac{final\_temp}{initial\_temp}\right)$$

The net entropy change for the system is determined.

3. Results and Discussion:

Question 1: Heat Discarded in a Power Plant

The calculated values are as follows:

3.1.1 Matlab Results:

Carnot efficiency ($Carnot\_eff$): 0.4957
Thermal efficiency ($Thermal\_eff$): 0.3470
Maximum work (W_Max): 396581.20 kW

Actual work (W_Actual): 277606.84 kW
Heat discarded ($Q\_Discarded$): 118974.36 kW

3.1.2 Discussion:

The thermal efficiency of the power plant is found to be 34.70%, and the heat discarded to the river is 118974.36 kJ/s. This indicates that the actual efficiency of the power plant is 70% of the maximum possible efficiency.

Question 2: Entropy Changes during Quenching Process

The calculated values are as follows:

3.2.1 Matlab Results:

Entropy change of the steel casting ($\boldsymbol{Entropy\_Casting}$): -16.33 kJ/K
Entropy change of the oil ($\boldsymbol{Entropy\_Oil}$): 26.13 kJ/K
Net entropy change for the system ($\boldsymbol{Net\_Entropy}$): 9.81 kJ/K

3.2.2 Discussion:

The negative entropy change for the steel casting and the positive change for the oil suggest an overall increase in disorder during the quenching process. The net entropy change for the system is positive, indicating an overall increase in entropy, in line with the second law of thermodynamics.

General Discussion

Comparing the results from both questions, we observe that while the power plant operates at a reduced efficiency (70% of Carnot), the quenching process results in a net increase in entropy, emphasizing the irreversible nature of these thermodynamic processes.

Assumptions made during the calculations include idealized conditions and no heat losses during the quenching process.

4. Conclusion/Summary::

In conclusion, this analysis provides valuable insights into the thermal efficiency of a power plant and the entropy changes during a material quenching process. The findings contribute to a better understanding of thermodynamic principles in power generation and material processing, aiding in the optimization of these processes.

5. Appendix:

Matlab code:

```
%Question 1
%Defining all the variables.
T_High=585; %Temp. in kelvin
T_Low=295; %Temp. in Kelvin
Power_Rate=800000; %kW

%Calculating Carnot efficiency
Carnot_eff=1-(T_Low/T_High); %Carnot Efficiency which is the maximum we can
achive.

%Calculating Thermal Efficiency
Thermal_eff= 0.7*Carnot_eff; % Thermal Efficiency is 70% of Carnot Efficiency.
```

```
%Calculating Maximum Work
W_Max=Power_Rate*Carnot_eff; %Maximum work that can drown from the Power Plant.

%Calculating Actual Work
W_Actual=Power_Rate*Thermal_eff; %Actual work that can drown from the Power Plant.

%Calculating Heat Discarded
Q_Discarded=W_Max-W_Actual; %Heat that discarded to the river.

%Printing the Result
fprintf('Heat discarded to the river at rated power: %.2f KJ/s \n',Q_Discarded)

%Question 2
%Properties of steel Casting
m_Casting=40; % Kg
Cp_Casting=0.5; % (KJ/Kg.K)
Init_Temp_Casting=450; % in °C

%Properties of Oil
m_Oil=150; % Kg
Cp_Oil=2.5; % (KJ/Kg.K)
Init_Temp_Oil=25; % in °C

%Changing Temp. from °C to K (Kelvin)
Temp_Casting=Init_Temp_Casting+273.15; % in K
Temp_Oil=Init_Temp_Oil+273.15; % in K

%Calculating intermediate Temp.
Inter_Temp=((m_Casting*Cp_Casting*Temp_Casting)+(m_Oil*Cp_Oil*Temp_Oil))/(m_Castin
g*Cp_Casting+m_Oil*Cp_Oil); % in K

%Entropy change of Casting
Entropy_Casting=m_Casting*Cp_Casting*log(Inter_Temp/Temp_Casting); %Entropy change
of Casting, when Casting is quenched in oil.

%Entropy change of Oil
Entropy_Oil=m_Oil*Cp_Oil*log(Inter_Temp/Temp_Oil); %Entropy Change of Oil, when
casting is quenched in Oil.

%Entropy change when both taken
Net_Entropy=Entropy_Oil+Entropy_Casting; %Net Entropy change when both Oil and
Casting are taken.

%Printing all the results.
fprintf('Entropy chnage of steel casting: %.2f KJ/s \n',Entropy_Casting)
fprintf('Entropy change of Oil: %.2f KJ/s \n',Entropy_Oil)
fprintf('Entropy change of Net systen: %.2f KJ/s \n',Net_Entropy)
```