Dataset on thermodynamics performance analysis and optimization of a reheat – regenerative steam turbine power plant with feed water heaters

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A B S T R A C T

Steam power plants have a considerable potential to meet the growing energy demand, but its dependence on conventional fossil fuels has hampered its viability. One of the ways to minimize fuel consumption and upgrade the performance of a Rankine cycle is by incorporating closed feedwater heaters (FWHs). The datasets contained in this paper are thermodynamic performance analysis carried out on reheat – regenerative steam power plant with FWHs using CyclePad V2.0 software. The thermodynamic performance indices assessed are thermal efficiency, network output, heat rate, fuel consumption, boiler efficiency and specific steam consumption. Result obtained show that an increase in the number of FWHs decreases the fuel consumption, heat rate, heat rejected in condenser and heat input to the cycle. This effect

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invariably can lead to a reduction in operating cost and environmental impacts.

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Specifications Table

| Subject                  | Mechanical Engineering |
|--------------------------|------------------------|
| Specific Subject area    | Thermodynamics and Thermal Engineering |
| Type of Data             | Tables, Figures and graphs |
| How Data Were Acquired   | Technical data sheet, analysed using software and processed output data |
| Data Format              | Secondary and analysed |
| Parameters for Data Collection | Temperature, pressure, enthalpy, power output, specific fuel consumption, heat rate and thermal efficiency inputs/outputs |
| Description of Data Collection | Inputs temperature and pressure and design parameters of the selected steam power plant were obtained from the efficiency department, Egbin Steam Power Plant, Lagos, Nigeria. |
| Data source location     | Efficiency Department, Egbin Steam Power Plant, Lagos, Nigeria |
| Data Accessibility       | Data are available within this article |
| Related Research Article | Oyedepo, S.O, Fakeye B. A, Mabinuori, B, Babalola, P.O, Leramo, R.O, Kilanko, O, Dirisu J, O, Udo, M, Efemwenkiekie U. K, and Oyebanji J.A, Thermodynamics Analysis And Performance Optimization of a Reheat – Regenerative Steam Turbine Power Plant with Feed Water Heaters, Fuel, 280:118,577 |

Value of the Data

- The thermodynamics model data of regenerative- reheat steam power plant can be used to predict the performance indices (thermal efficiency, heat rate, specific fuel consumption, specific steam consumption etc.) of a steam power plant.
- The dataset helps power plant Engineer to predict the maximum number of FWHs required for optimum performance of a steam power plant.
- The dataset in this study can be used to optimize the performance of a regenerative – reheat steam power plant.
- This dataset with other set can be used to assess the exergetic efficiency of regenerative – reheat steam power plant.
- We assessed the effect of variation in the number of closed FWH on the performance indices of steam power plant.
- The data reveals that as the number of FWHs increases, so is the total temperature rise of feed water ($\Delta t_{fw}$). Hence, by regeneration, less becomes the heat added to water in the boiler, more becomes the mean temperature of heat addition, and more is the cycle efficiency.

1. Data Description

The thermodynamic properties of steam, including pressure, temperature, enthalpy, entropy, specific volume and mass flow rates at state points of reheat – regenerative cycle (Summary of the operating parameters can be found in [1]) were calculated using cyclepad V2.0 and presented in Tables 1–5 for Rankine cycle without FWH, with 1, 2, 3, and 4 FWHs, respectively. The layout of the reheat – regenerative cycle with 4-FWHs generated using cyclepad as a sample can be found in [1].
Table 1
State thermodynamic properties for Rankine cycle without FWH.

| Location | T(°C) | P(kPa) | h(kJ/kg) | s(kJ/kgK) | \( \dot{m} \) (kg/s) |
|----------|------|-------|---------|----------|-----------------|
| S1       | 545  | 12,990| 3457    | 6.59     | 0.0267          |
| S2       | 538  | 12,500| 3444    | 6.59     | 0.0275          |
| S3       | 541  | 12,500| 3452    | 6.60     | 0.0276          |
| S4       | 538  | 12,295| 3446    | 6.60     | 0.0280          |
| S5       | 42.67| 8,500 | 2071    | 6.60     | 13.490          |
| S6       | 42.67| 8,500 | 2071    | 6.60     | 13.490          |
| S7       | 43.08| 12,990| 191.8   | 6.078    | 0.0010          |

Table 2
State thermodynamic properties for the reheat-regenerative cycle with one FWHs.

| Location | T(°C) | P(kPa) | h(kJ/kg) | s(kJ/kgK) | \( \dot{m} \) (kg/s) |
|----------|------|-------|---------|----------|-----------------|
| S1       | 545  | 12,990| 3457    | 6.59     | 0.0267          |
| S2       | 538  | 12,500| 3444    | 6.59     | 0.0275          |
| S3       | 541  | 12,500| 3452    | 6.60     | 0.0276          |
| S4       | 538  | 12,295| 3446    | 6.60     | 0.0280          |
| S5       | 42.67| 8,500 | 2071    | 6.60     | 13.490          |
| S6       | 42.67| 8,500 | 178.7   | 0.6078   | 0.0010          |
| S7       | 43.06| 12,295| 191.1   | 0.6078   | 0.0010          |
| S8       | 538.0| 12,295| 3446    | 6.60     | 0.0280          |
| S9       | 55.53| 12,295| 242.9   | 0.7685   | 0.0010          |
| S10      | 55.56| 12,990| 243.6   | 0.7685   | 0.0010          |

Table 3
State thermodynamic properties for the reheat-regenerative cycle with two FWHs.

| Location | T(°C) | P(kPa) | h(kJ/kg) | s(kJ/kgK) | \( \dot{m} \) (kg/s) |
|----------|------|-------|---------|----------|-----------------|
| S1       | 545.0| 12,990| 3457    | 6.59     | 0.0267          |
| S2       | 538.0| 12,500| 3444    | 6.59     | 0.0275          |
| S3       | 538.0| 12,500| 3444    | 6.59     | 0.0275          |
| S4       | 541.0| 12,500| 3452    | 6.60     | 0.0276          |
| S5       | 538.0| 12,295| 3444    | 6.60     | 0.0280          |
| S6       | 538.0| 12,295| 3446    | 6.60     | 13.490          |
| S7       | 42.67| 8,500 | 2017    | 6.60     | 13.490          |
| S8       | 42.67| 8,500 | 178.7   | 0.6078   | 0.0010          |
| S9       | 43.06| 12,295| 191.1   | 0.6078   | 0.0010          |
| S10      | 538.0| 12,500| 3444    | 6.59     | 0.0275          |
| S11      | 538.0| 12,295| 3446    | 6.60     | 0.0280          |
| S12      | 56.77| 12,295| 248.0   | 0.7848   | 0.0010          |
| S13      | 56.78| 12,500| 248.2   | 0.7841   | 0.0010          |
| S14      | 125.9| 12,500| 537.4   | 1.5800   | 0.0011          |
| S15      | 126.0| 12,990| 538.0   | 1.5800   | 0.0011          |

To assess the optimal performance of FWH, the number of FWHs was increased from 5 to 10, and the performance parameter – heat rate is presented in Fig. 1. Fig. 1 compares the computed heat rate (using CyclePad) for the power cycle without FWH and with one to ten FWHs.

The total enthalpy rise and total temperature rise of FWH in the reheat - regenerative cycle were computed and presented in Fig. 2. Fig. 2 shows the total enthalpy rise and total temperature rise for the cycle without FWH and cycle with 1 to 10 closed FWHs.
Table 4
State thermodynamic properties for reheat-regenerative cycle with three FWHs.

| Location | T(°C) | P(kPa) | h(kJ/kg) | s(kJ/kgK) | v(m³/kg) | m(kg/s) |
|----------|-------|--------|----------|-----------|----------|---------|
| S1       | 545   | 12,990 | 3457     | 6.59      | 0.0267   | 110.6   |
| S2       | 538   | 12,500 | 3444     | 6.59      | 0.0275   | 110.6   |
| S3       | 538   | 12,500 | 3444     | 6.59      | 0.0273   | 94.35   |
| S4       | 541   | 12,295 | 3452     | 6.60      | 0.0276   | 94.35   |
| S5       | 538   | 12,295 | 3446     | 6.60      | 0.0280   | 94.35   |
| S6       | 538   | 12,295 | 3446     | 6.60      | 0.0280   | 92.46   |
| S7       | 538   | 12,295 | 3446     | 6.60      | 0.0280   | 87.35   |
| S8       | 42.67 | 8.50   | 2071     | 6.60      | 0.0275   | 13.490  |
| S9       | 42.67 | 8.50   | 178.7    | 0.6078    | 0.0010   | 87.35   |
| S10      | 538   | 12,500 | 3444     | 6.59      | 0.0275   | 16.22   |
| S11      | 538   | 12,295 | 3446     | 6.60      | 0.0280   | 1.89    |
| S12      | 538   | 12,295 | 3446     | 6.60      | 0.0280   | 5.11    |
| S13      | 43.06 | 12,295 | 191.1    | 0.6078    | 0.0010   | 87.35   |
| S14      | 86.30 | 12,295 | 371.0    | 1.1400    | 0.0010   | 92.46   |
| S15      | 86.30 | 12,295 | 371.0    | 1.1400    | 0.0010   | 92.46   |
| S16      | 101.00| 12,295 | 432.4    | 1.3100    | 0.0010   | 94.35   |
| S17      | 101.00| 12,500 | 432.7    | 1.3100    | 0.0010   | 94.35   |
| S18      | 203.90| 12,500 | 874.4    | 2.3500    | 0.0012   | 110.6   |
| S19      | 204.00| 12,990 | 875.0    | 2.3500    | 0.0012   | 110.6   |

Table 5
State thermodynamic properties for the reheat-regenerative cycle with four FWHs.

| Location | T(°C) | P(kPa) | h(kJ/kg) | s(kJ/kgK) | v(m³/kg) | m(kg/s) |
|----------|-------|--------|----------|-----------|----------|---------|
| S1       | 545   | 12,990 | 3457     | 6.59      | 0.0267   | 110.6   |
| S2       | 538   | 12,500 | 3444     | 6.59      | 0.0275   | 110.6   |
| S3       | 538   | 12,500 | 3444     | 6.59      | 0.0273   | 94.35   |
| S4       | 541   | 12,500 | 3452     | 6.60      | 0.0276   | 94.35   |
| S5       | 538   | 12,295 | 3446     | 6.60      | 0.0280   | 94.35   |
| S6       | 538   | 12,295 | 3446     | 6.60      | 0.0280   | 94.48   |
| S7       | 538   | 12,295 | 3446     | 6.60      | 0.0280   | 94.48   |
| S8       | 538   | 12,295 | 3446     | 6.60      | 0.0280   | 94.48   |
| S9       | 42.67 | 8.50   | 2071     | 6.60      | 0.0275   | 13.490  |
| S10      | 42.67 | 8.50   | 178.7    | 0.6078    | 0.0010   | 92.46   |
| S11      | 43.06 | 12,295 | 191.1    | 0.6078    | 0.0010   | 92.46   |
| S12      | 101.00| 12,295 | 432.4    | 1.3100    | 0.0010   | 94.35   |
| S13      | 101.00| 12,500 | 432.7    | 1.3100    | 0.0010   | 94.35   |
| S14      | 203.90| 12,500 | 874.4    | 2.3500    | 0.0012   | 110.6   |
| S15      | 204.00| 12,990 | 875.0    | 2.3500    | 0.0012   | 110.6   |

2. Experimental Design, Materials, and Methods

The primary data (plant’s operating parameters) were collected from efficiency department of Egbin Steam Power Plant. Egbin power plant consists of 6 units of 220 (6 × 220 MW) reheat-regenerative cycle. It is dual fired (gas and heavy oil) system with modern control equipment, single reheat and six stages regenerative feedwater heating [2, 3]. The design basis of each unit is a nominal 220 MW Reheat-Regenerative cycle [4].
Thermodynamic performance analysis and optimization of the selected reheat – regenerative steam power plant were carried out using cyclepad. Rankine cycle was modified using CyclePad, and the effects of regeneration on the cycle’s thermal efficiency, specific fuel consumption, boiler efficiency, specific steam consumption and heat rate were examined.

CyclePad is an articulate virtual laboratory software for analysis of thermodynamic cycles consisting of a collection of components which either takes in heat energy and produces work energy, or takes in work energy and produces transfer of heat energy. And these components
are connected together in some appropriate fashion. The components CyclePad recognises include compressors, turbines, heaters, coolers, pumps, mixers, splitters, throttles, and heat exchangers. CyclePad describes connections in terms of the properties of the working fluid flowing between the components. CyclePad performs steady-state analyses of both open and closed cycles. It works in two phases i.e. build mode and analysis mode. In the first phase (build mode), user uses a graphical editor to place components and connect them with stuffs. While in the analysis mode, user specifies the working fluid in use, the modeling assumptions that have to be made and numerical values for the properties of components. As soon as CyclePad receives these information, it draws conclusions based on the design. This includes the structure of the thermodynamic cycle design, in terms of the physical parts and processes of the cycle and how they are connected to one another; plots the T-s and P-v diagrams of the cycle to understand where the working fluid is in its property space. CyclePad is being considered in this dataset work due to its unique features: easy calculation, facilitate sensitivity, ability to detect physically impossible design and to provide numerical reasoning and interface interaction for the users [5].

In this data, the operation of steam power plant is considered in the steady-state condition. The pressure loss throughout the pipelines is assumed negligible. Applying the steady flow energy equation to each of the processes on the basis of a unit mass of fluid, and neglecting changes in kinetic and potential energy, the work and heat quantities are evaluated in terms of the properties of the fluid. Detailed energy analysis of each component to determine the reheat – regenerative steam turbine power plant’s performance indices (i.e. cycle efficiency, network output, heat rate, specific steam consumption, specific fuel consumption) using cyclePad software can be found in [1].

Ethic Statement

This study was carried out in accordance with the U.K Guidelines

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships which have, or could be perceived to have, influenced the work reported in this article.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi: 10.1016/j.dib.2020.106086.

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