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APPRAISAL OF THE PERFORMANCE OF A MARINE GAS TURBINE USED FOR ELECTRICAL POWER GENERATION

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ABSTRACT

The appraisal of the performance of a marine gas turbine used for electrical power generation on the basis of the comparative study of the influence of the ambient temperature and the turbine inlet temperature has been performed. The appraisal encompasses studying of the logsheets that were used when the gas turbine was in operation and the study took ten weeks. The marine gas turbine engine which this evaluation is being performed is the ABB:ALSTOM, Aero – Derived of 75MW capacity used to generate power for electricity at Afam III Power Station in Oyigbo Local Government Area of Rivers State. The result obtained shows that both the ambient temperature and the turbine inlet temperature has great effect on the gas turbine performance. While an increase in ambient temperature will cause a decrease in the power out and thermal efficiency, an increase in the turbine inlet temperature will result to an increase in both the power output and thermal efficiency thereby enhancing productivity. Also, the net work increases as both the turbine inlet temperature and ambient temperature increases thereby requiring much energy at both high turbine inlet temperature and ambient temperature. Practically, it is recommended that at ambient temperature of 31^{0}C with a corresponding turbine inlet temperature is required for optimal power generation.

Keywords: Ambient Temperature, Turbine Inlet Temperature, Thermal Efficiency, Net Work, Power Output

I. INTRODUCTION

Gas turbine engines obtain their power from burning fuel in the combustion chamber. However, the fast flowing combustible gases in the combustion chamber is used to move the turbine [1]. Precisely, the most important advancement that the gas turbine has gone through experimentation is possibly the increase in the gas turbine inlet temperature. That was achievable due to advancements on the turbine blade cooling techniques coupled with the metallurgical improvements. The turbine inlet temperature absolutely makes references to the exhaust temperature from the combustion chamber [2]. Sundries techniques has been implored or utilized by very - many known researchers to achieve more excellent thermal efficiency of the turbines, specifically, the gas turbine. One of such techniques or methods is the increase in the gas turbine inlet temperature [3][4].In numerous cases, the estimated: which are the approximated parameters, are not always optimal inside the gas turbine. It is therefore pertinent to regulate the input parameters with the target of increasing the performance of the gas turbine [5]. However, it has been satisfactorily established that the performance of a gas turbine can be qualified as regards to its efficiency, specific fuel consumption, power output and in addition to the work ratio. Precisely, there are many parameters that affect the gas turbine performance such as the compressor compression ratio, combustion inlet temperature and turbine inlet temperature [6][7].

The evaluation of the influence of ambient temperature on the performance of the Trans-Amadi gas turbine plant has been carried out by [8]. The evaluation took thirteen months during which plant data were monitored and operational logsheets studied and the result of the study shows that a 1^{0}C rise of the ambient temperature will cause 0.12% decrease in power output, 0.12% increase in power differential, 1.17% decrease in the thermal efficiency, 27.18% increase in heat rate and 3.57% increase in the specific fuel consumption.

The thermodynamic performance analysis of a gas turbine power plant was studied [9]. In the appraisal, the variation of operating conditions like compressor ratio, turbine inlet temperature, exhaust temperature, air fuel ratio, isentropic efficiency, turbine efficiency and the compressor inlet temperature on the performance of the gas turbine thermal efficiency, compressor work, power output, specific fuel consumption and heat rate were assessed. The MATLAB Software was used in developing the programme of the performance model of

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the gas turbine and the results show that the compressor ratio, turbine inlet temperature, air fuel ratio as well as the isentropic efficiency has a great influence on the thermal efficiency.

The effect of compression ratio on the performance of combined cycle gas turbine was investigated and reported by [10]. The work used a complete model of combined cycle gas turbine power plant with effect of the gas turbine peak compression ratio and the overall efficiencies for combined cycle gas turbine after using the MATLAB software in the simulation model was found to be higher when compared to gas turbine plants.

Furthermore, the present work will look at the appraisal of the performance of a marine gas turbine used for electrical power generation on the basis of the comparative assessment of the influence of the ambient temperature and the turbine inlet temperature and also look for possible recommendation.

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II. METHODOLOGY

The appraisal encompasses direct measurement and studying of the logsheets that were used during the period of ten weeks which this research was performed. The parameters investigated during the data appraisal were pressure, temperatures and mass flow rates at various points in the gas turbine while the parameters that could not be collated directly, a suitable thermodynamics equations and principles were applied [11, 12, 13]. Precisely, the gas turbine engine which this evaluation is being performed is the ABB: ALSTOM, Aero – Derived Marine Type of 75MW used for power generation at Afam III Station which is situated at Oyigbo Local Government Area, Rivers State, Nigeria [14].

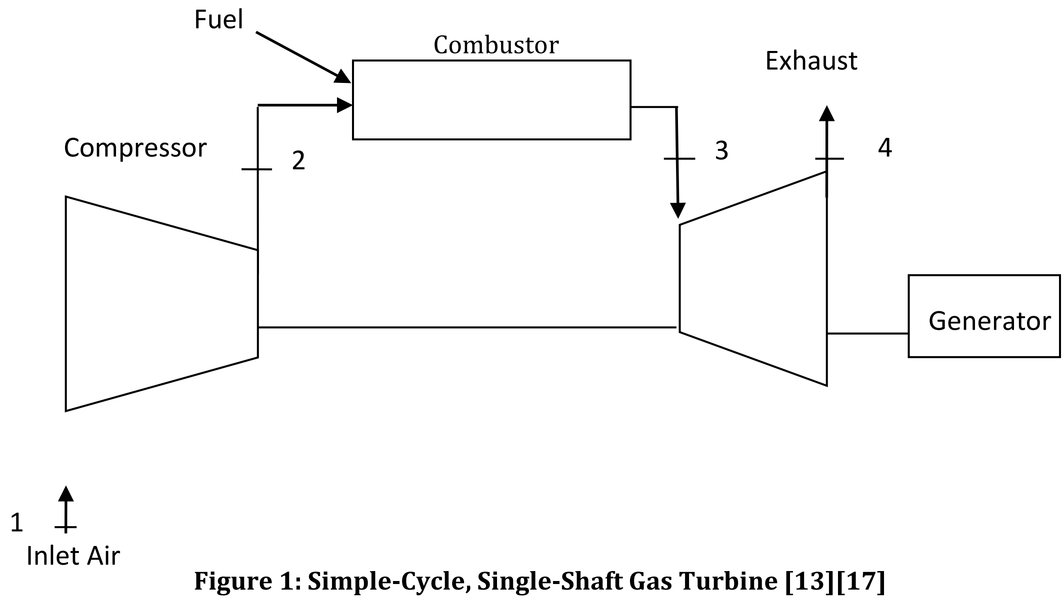

Figure 1: Simple-Cycle, Single-Shaft Gas Turbine [13][17]

Considering the various point of the single – shaft gas turbine which operates on a Brayton Cycle as well represented in Figure 1, the following relation can be deduced [15][16].

Compressor work = $h_2 - h_1 = C_p (T_2 - T_1)$ (1)

Turbine work = $h_3 - h_4 = C_p (T_3 - T_4)$ (2)

Heat Added = $h_3 - h_2 = C_p (T_3 - T_2)$ (3)

Heat Rejected = $h_4 - h_1 = C_p (T_4 - T_1)$ (4)

Net Work = $W_T - W_C$ (5)

Thermal Efficiency = $\frac{Net\ Work}{Heat\ Added}$ (6)

III. RESULTS AND DISCUSSION

RESULTS:

The values of T_1,T_2,T_3 and T_4 are in Table 1 and they were obtained from direct reading of the logsheets that was used in operation while Table 2 contains the values of the compressor work, turbine work, heat added, net work and thermal efficiency were obtained by calculation using equations: 1, 2, 3, 5 and 6 respectively. The values utilized for the calculation of the pressure ratios were presumed to be constant and then the values were compared with [14][18]. The effects of the ambient temperature and the turbine inlet temperature on the power output, net work and the thermal efficiency were plotted using Excel software (Figure 2 – figure 4) and Figure 5 is a bar chart representing the relationship of the temperatures to the turbine working parameters.

Table 1. Parameters of the Gas Turbine obtained from Direct Reading

S/No.	T_1(°C)	T_2(°C)	T_3(°C)	T_4(°C)	Power Output(MW)
1	27	176	940	538	30
2	30	180	1232	733	49
3	32	183	1237	736	49
4	34	186	1238	737	49
5	36	189	1240	738	52
6	38	192	1242	739	50
7	40	195	1246	742	45
8	42	198	1249	744	47
9	44	201	1252	746	33
10	46	201	1256	749	41

Table 2. Parameters Obtained from Calculation

S/No.	W_c KJ/Kg	W_TKJ/Kg	Q_{added} KJ/Kg	W_{net}(KJ/Kg)	η(%)
1	150	405	768	255	0.354
2	151	502	1057	351	0.352
3	152	504	1059	352	0.332
4	153	504	1057	351	0.332
5	154	505	1056	351	0.332
6	155	505	1055	350	0.332
7	156	507	1056	351	0.332
8	157	508	1056	351	0.332
9	158	509	1056	351	0.332
10	159	510	1057	351	0.332

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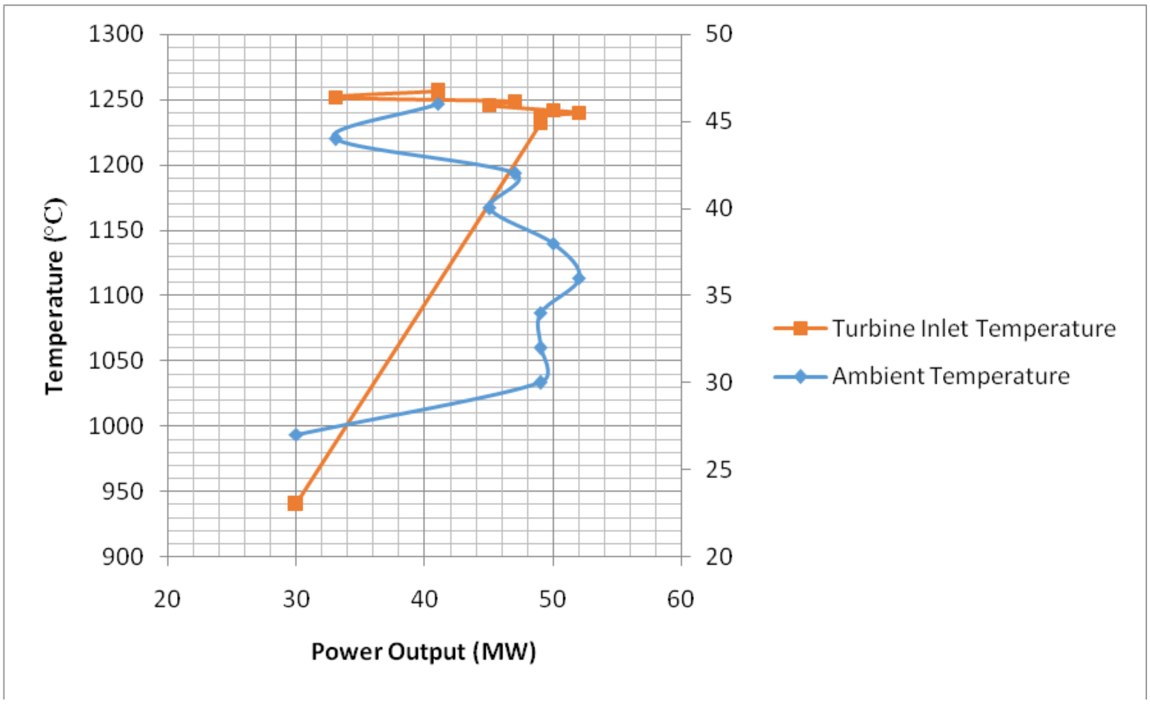

Figure 2: Power Output against the Ambient and Turbine Inlet Temperatures

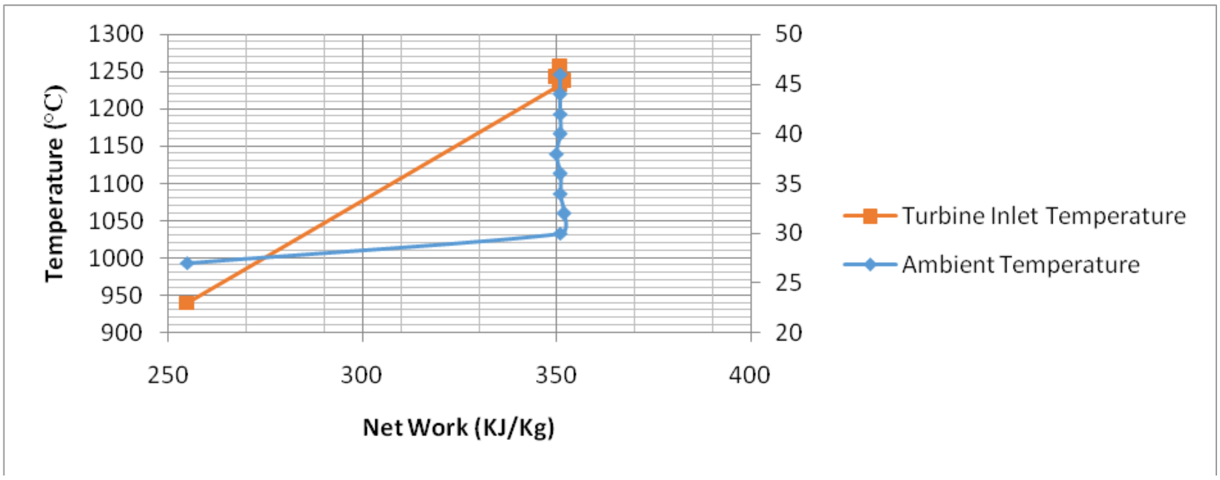

Figure 3: Net Work Against the Ambient and Turbine Inlet Temperatures

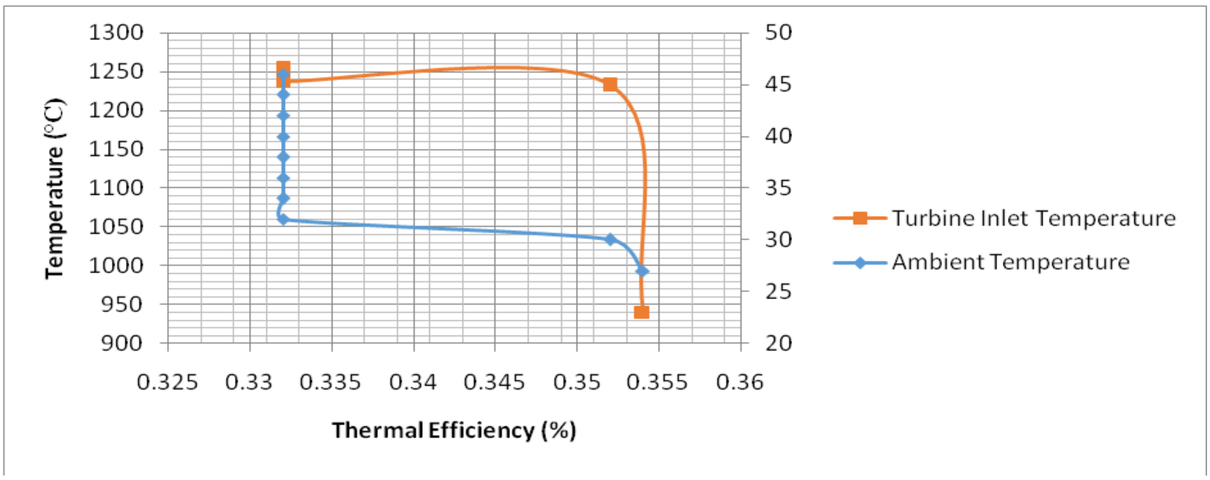

Figure 4: Thermal Efficiency Against the Ambient and Turbine Inlet Temperatures

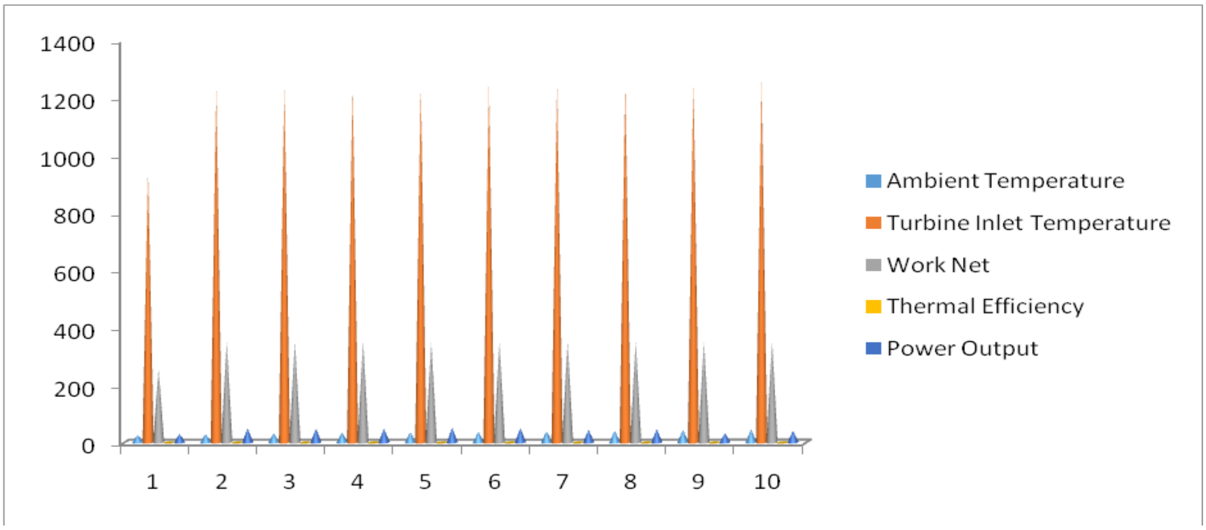

Figure 5: Bar Chart Representing the Relationship between the Temperatures and the Turbine Working Parameters

DISCUSSION:

The Figure 2 depicts that the power output increases at a high turbine inlet temperature of 1250°C and it decreases at high ambient temperature of 44°C and it is not favorable for power generation. Figure 3 represents that there is slightly increase of the net work as both the turbine inlet temperature and ambient temperature increases at 1240°C and 46⁰C respectively and it shows that much work is done at both higher turbine inlet temperature and ambient temperature. Figure 4 illustrates that as the thermal efficiency increases at a high turbine inlet temperature of 1260⁰C while the thermal efficiency decreases at a high ambient temperature of 46⁰C and it shows that low ambient temperature is recommended for optimal power generation. Finally, the Figure 5 shows the relationship between the temperatures and the working parameters and it reveal that there is fluctuation in the power output when considering from section 1 in the bar chart to section 10.

IV. CONCLUSION

The study has revealed that both the turbine inlet temperature and the ambient temperature have great effect on the gas turbine plant. While an increase in ambient temperature will cause a decrease in the power out and thermal efficiency, an increase in the turbine inlet temperature will result to an increase in both the power output and thermal efficiency thereby enhancing productivity. Also, the net work increases as both the turbine inlet temperature and ambient temperature increases thereby requiring much energy at both high turbine inlet temperature and ambient temperature. Practically, it is recommended that at ambient temperature of 31⁰C with a corresponding turbine inlet temperature is required for optimal power generation.

Nomenclature:

C_p= Specific Heat Capacity of the Product (KJ/KgK)

h = Specific Enthalpy (KJ/KgK)

MW = Meggawatts

η = Thermal Efficiency (%)

Q_{added}= Heat Added or Heat Supplied (KJ/Kg)

T_1 = Ambient Temperature (⁰C)

T_2 = Compressor Exit Temperature (⁰C)

T_3 = Turbine Inlet Temperature (⁰C)

T_4 = Exhaust Temperature (⁰C)

$\dot{W}_c$ = Compressor Work (KJ/Kg)

$\dot{W}_{Net}$= Turbine Net Work (KJ/Kg)

$\dot{W}_T$ = Turbine Work (KJ/Kg)

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