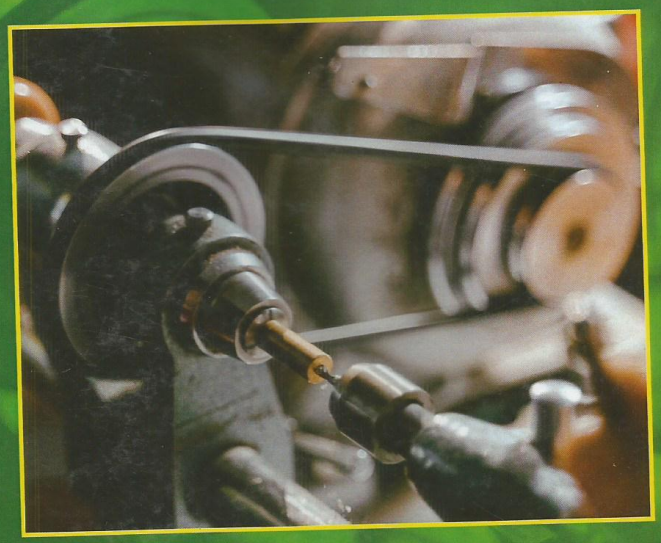
Journal of NIMechE

Journal of the Nigerian Institution of Mechanical Engineers

VOL. 10, NO.2 ISSN 2141 - 2987 SEPTEMBER, 2021



The Nigerian Institution of Mechanical Engineers

(A Division of The Nigerian Society of Engineers)

Journal of the Nigerian Institution of Mechanical Engineers

SEPTEMBER, 2021
ISSN 2141 - 2987

JOURNAL OF THE NIGERIAN INSTITUTION OF MECHANICAL ENGINEERS
SEPTEMBER, 2021 VOL 10 NO 2 ISSN 2141-2987

CONTENT

ISSN 2121-2987

Journal of NIMechE Vol.10 No. 2, pp 57-61
Printed in Nigeria

22, The Nigerian Institution of Mechanical
Division of Nigerian Society of Engineers)

DEVELOPMENT OF AN UPDRAFT GASIFIER FOR ONYEAMA COAL

A.J Agabi[1a], A.Nasir[1] , O. J. Okegbile[1] , A.S. Kovo[2] , A.B. Garba[1]

[1] Department of Mechanical Engineering, Federal University of Technology, Minna,

[2] Department of Chemical Engineering, Federal University of Technology, Minna

[a] Email: nimilen@yahoo.com

ABSTRACT

The design and MATLAB simulation of the operating parameter of Onyeama coal in an updraft gasifier was investigated. The operating parameters considered are: power rating, air required, fuel consumption, hopper volume, time, reactor diameter and height. These results show that there exist a linear relationship of all the operating parameter with the power rating. It can be deduced that the sizing of the updraft (diameter and height) increased commensurately to increase in the power rating requirement and the operational time respectively. The lower values of the power rating obtained for the reactors diameter is a function of the coals heating value as well as the power rating requirement. The power rating should not be more than 700KW to obtain the optimal fuel consumption requirement. It can be established that onyeama coal proved to be more conservative in terms of the amount of coal that would be required for a particular rating.

Keywords: Operating parameter, MATLAB, onyeama coal and simulation

1.0 INTRODUCTION

Energy and good healthy condition has been reported to be the most significant aspect of life necessary for the societies (Vikrant and Argawal, 2019). The global need of energy sources such as crude oil, coal and natural gas with 33.28%, 28.11% and 24.13% in ranking has been reported in 2016 as the highest energy sources consumed globally, (Shakorfow, 2016) (Chukwu et al., 2016). Among the three sources of energy, coal is the cheapest and least expensive as compared with crude oil and natural gas that power generation. The design of any gasifier is usually accomplished with many assumptions in operating parameter, kinetic and thermodynamic effect that affect the gasification of the coal (Akanksha et al., 2018). These factors vary from one coal source to another. Another factor mentioned are depleting (Shakorfow, 2016). It is clear that research into coal as a fuel is not only timely but important at this period in the world energy sources (Shakorfow, 2016) (Akanksha et al., 2018). However the use of coal as an energy source is always accompanied with higher emission of carbon monoxide and carbon dioxide (Vikrant and Argawal, 2019). The design of gasifier is one of the greater factors in the development of a gasifier for the gasification of coal for

is the operating parameter and has been reported as the most significant factor that affects the successful operation of coal gasification (Akanksha et al., 2018). In this present work, the design and simulation of the operating parameter of an updraft gasifier for Onyeama coal is studied.

2.0 MATERIALS AND METHOD

The power requirement of a gasifier is determined by the fuel consumption rate which is empirically the amount of fuel (coal) that must be burnt per specific time in order to achieve the required amount of power of the gasifier. The size of the reactor is a function of the diameter of the cross-section of the cylinder where the fuel is being burnt. This is generally a function of the amount of the fuel consumed per unit time (FCR) to the specific gasification rate (SGR) of the fuel. The height of the gasifier which plays an important role in the performance of the gasifier is the total distance from the top and the bottom end of the reactor. This determines how long the gasifier would be operated in one loading of fuel. Basically, it is a function of a number of variables such as the required time to operate the gasifier (t), the specific gasification rate (SGR), and the density of the fuel.

2.1 Model Formulation Concept

The updraft coal gasifier was designed using relevant design equations and criteria as shown in Table 2. MATLAB software is used in determining the operating parameter using Onyeama coal with composition displayed in Table 1. The model equations were adopted from the work of Hong et al (2009). The core essence of the simulation was to see the trend in the design sizing of the system if the **power requirements, reaction times as well as the inherent coal were not constant**. Hence the simulation graphs will give an outline for knowing what the system sizing will be if any parameter is selected within the range of the three design factors as (i.e. power requirements, reaction times as well as the inherent coals).

Table 1: Composition of Onyeama coal

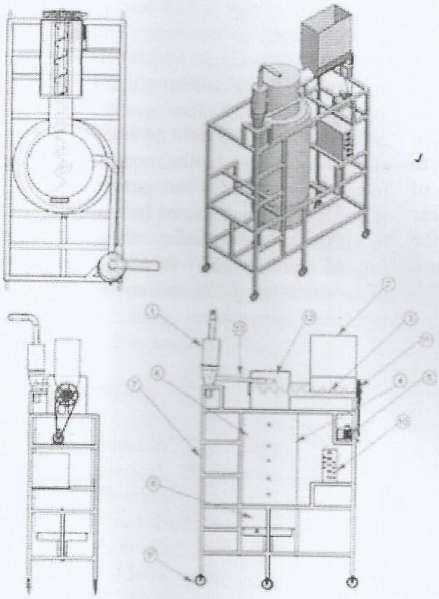
Proximate analysis		Ultimate analysis	
Moisture %	5.87	H%	3.8
Volatile matter	29.61	C%	86.55
Fixed carbon	63.61	N%	1.2
Ash	1.25	S%	0.6
Calorific value	33.33	ASH	1.25

(Source: Chukwu et al., 2016)

2.2 Design Requirements

Table 2 Design Parameters and their deductions

Design Parameters	**Symbols**	**Formula**	**Values**	**Units**
Fuel Consumption Rate	$\dot{m}_f$	$FCR = \dot{m}_f = \frac{\text{Power Required}}{LCV \times \eta_{thermal}}$	**108.36**	Kg/hr
Diameter of Reactor	D_r	$D_r = \left(\frac{4 \times \dot{m}_f}{SGR \times \pi}\right)^{0.5}$	**630**	Mm
Height of Reactor	H_r	$H_r = 1.4 \times \left(\frac{SGR \times t}{\rho_f}\right)$	**1460**	Mm
Power Required	P	$P = m_f \times \dot{LCV} \times \eta_{thermal}$	5	kW



S/N	PART DESCRIPTION	MATERIALS	QTY	REMARKS
13.	PIPE	MILD STEEL	1	STANDARD
12.	REACTOR COVER	MILD STEEL	1	CONSTRUCTED
11.	FLY WHEEL	MILD STEEL	1	STANDARD
10.	ELECTRIC REGULATOR	-	1	STANDARD
9.	CASTOR WHEEL		6	STANDARD
8.	ASH POT	MILD STEEL	1	CONSTRUCTED
7.	STANDE FRAME	MILD STEEL	1	CONSTRUCTED
6.	REACTOR	MILD STEEL	1	CONSTRUCTED
5.	MOTOR DRIVE	-	1	STANDARD
4.	INSULATOR	COMPOSITE	1	CONSTRUCTED
3.	AUGER	MILD STEEL	1	CONSTRUCTED
2.	HOPPER	MILD STEEL	1	CONSTRUCTED
1.	CYCLONE	MILD STEEL	1	CONSTRUCTED

FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA
MECHANICAL ENGINEERING DEPARTMENT

DESCRIPTION: ASSEMBLY DRAWING OF THE 500W FLUIDIZED BED COAL GASIFIER (UPDRAFT) — SCALE: 1:1

	NAME	SIGNATURE	DATE
DRAWN BY:	ENGR. JOSEPH AKU AGABI		
REG. NO:	PG/SEET/2016/90		
SUPERVISORY TEAM :	ENGR. PROF. A. NASIR		
	ENGR. DR. O.J. OKEGBILE		
	ENGR. PROF. A.S. KOVO		

Figure 1: Assembly Drawing of the Gasifier

3.0 RESULTS AND DISCUSSION

Power rating and fuel consumption rate

Figure 2 displayed the plot of fuel consumption and power rating requirement for the updraft gasifier. As the power rating increases from 100kW to 1000kW, the fuel consumption rate also rises. Due to its high heating value, the coal has low economic fuel consumption close to that of the calculated fuel consumption of 108.6kg/hr. Equation (1) is the linear regression equation and the percent/residual curve displayed in Figure 3.

t.

Fuel consumption rate FCR (kg/h) = 0.080 + 0.154 Power required (kW) (1)

From Eq. (1), a linear relationship exists between fuel consumption with the power required for the gasification with a constant coefficient of 0.080. Inputting this in equation 1, the coefficient of power requirement for the gasification is 0.154. The Pred R-Squared has a value of 100%. While the Adj R-Squared also has a value of 100% and 0.168280 as standard deviation. Thus the model is significan

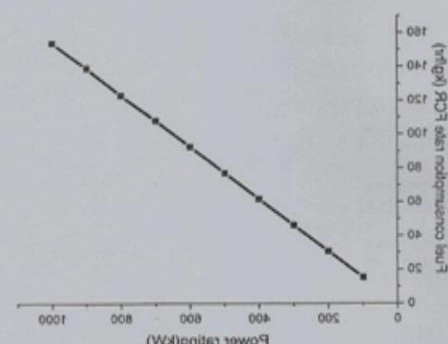


Figure 2: Variation of Fuel consumption rate and power required.

Figure 2 presents the residual plot for the analysis. Figure 2 showed the experimental value is close to the predicted values since the points are randomly distributed close to the line in the plot. It can be seen from the values of the Pred R-Squared and was close to 100.0% for the Adj R-Squared.

This work has shown that for optimal gasifier performance, the power rating is 700kW since the value of fuel consumption at 700kW power rating is 108Kg//hr, which is close to that of the calculated values 108.6Kg/hr.

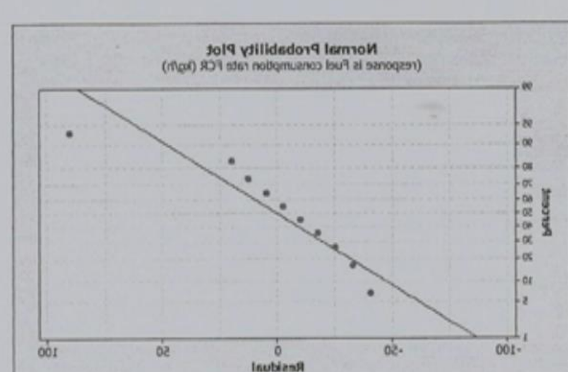


Figure 3: Residual plots for the fuel consumption and power rating

4.0 CONCLUSIONS

The design and MATLAB simulation of the operating parameter of Onyeama coal in updraft gasifier was investigated. The design operating parameters considered in the work are: power rating, air required, fuel consumption, hopper volume, time, reactor diameter and heights. These results show that there exist linear relationship of all the operating parameter with the power rating. It can be deduced that the sizing of the updraft gasifier (diameter and height) increased commensurately to increase in the power rating requirement and the operational time respectively.

REFERENCES

S. Vikrant and V. K. Agarwal, (2019). "Numerical Simulation of Coal Gasification In A Circulating Fluidized Bed Gasifier," *Brazilian J. Chem. Eng.*, vol. 16, no. 03, pp. 1289–1301.

A. M. Shakorfow (2016), "Operating and Performance Gasification Process Parameters," *Int. J. Sci. Res.*, vol. 5, no. 6.

M. Chukwu, C. O. Folayan, G. Y. Pam, (2016). Characterization of Some Nigerian Coals for Power Generation Journal of Combustion, Article ID 9728278, 11 pages

http://dx.doi.org/10.1155/2016/9728278

M. Akanksha ., G. Shalini ., S. Tripurari ., (2018). Effect of operating parameters on coal gasification. International Journal of Coal Science & Technology. Volume 5, Issue 2, pp 113–125.

T. Hong , C. Donglin and C. Jiuju (2009). "Effect of Operation Parameters on High Temperature Air Gasification." in *IEEE. Asia-Pacific Power and Energy Engineering Conference*

o