where:

$Exp(\dot{M}/P,T,F)$ is the expected value of melting rate in kg/min. given the independent variables P, T and F, $b_{oOk/es}$ is intercept of model IV, $b_{1Ok/es}$ is regression coefficient associated with air pressure of the model, $b_{2Ok/es}$ is regression coefficient associated with melting time of the model and $b_{3Ok/es}$ is regression coefficient associated with fuel consumed of the model.

4.2 ***Hypothesis 1: Testing model validity***

Model hypothesis: for a cupola furnace using OK/ES as fuel is presented as in equation 6:

$$H_0 : \beta_{jOk/es} = 0, \ j = 1, 2, 3$$

$$If\ H_0\ is\ rejected,\ then\ H_1 : at\ least\ one\ \beta_{jOk/es} \neq 0 \qquad (6)$$

This hypothesis is intended to test validity of the presence of a relation between melting rate of the furnace and the independent variables. If the null hypothesis is rejected, then there are some independent variables that do actually affect melting rate.

4.3 Hypothesis II: Individual testing of coefficients of the multiple linear regression models.

Hypothesis II for any independent variable is as presented in equation 7.

$$H_0 : \beta_{1-3Ok/es} = 0 \quad vs \quad H_1 : \beta_{1-3Ok/es} \neq 0 \qquad \ldots 7$$

The null hypothesis assumed that there was no statistically significant relationship between melting rate and any of the independent variables (blast pressure, melting time and fuel consumed).

4.4 Model Validation and Discussion

SPSS (version 16.0) was used to validate the data obtained in Table 2 and the results are shown in Table 3.

Table 3: Model Summary for a Cupola Furnace using OK/ES as Fuel

		ANOVA		COLLINEARITY DIAGNOSTICS					RESIDUALS		
Parameter	**Value**	**Parameter**	**Sum of squares**	**Parameter**	**Condition index**	**Coefficients**	**VIF**	**T-Statistic**	**Parameter**	**Mean (μ)**	**Std. Deviation (σ)**
R^2	0.999	Regression	6501.65	Constant (b_{0Okc})	1.00	35.204	-	0.542	Predicted value	46.973	24.312
F-Statistic	1808.837	Residual	9.585	P (b_{1Okc})	4.332	-35.079	1.004	-0.554	Residual	0	0.933
Significance of F-statistic	0.000	-	-	T (b_{2Okc})	118.346	0.931	-	2.666	-	-	-
				F(b_{3Okc})	566.218	1.796	-	1.238			

Scatter diagram shown in Figure 1 was plotted which clearly indicates the validity of initial selection of variables. The model summary shown in Table 3, gave a computed value for the R^2 as 0.999, thus indicating that the regression was significant as 99.9 % variation in melting rate could be accounted for by the control variables. The *ANOVA* analysis in the regression result, shown in Table 3, gave a computed value for the *F*-statistic as 1808.837 while the corresponding table value of 3.98 at 0.05 level of significance (q) and (2,11) degrees of freedom showed that the multiple linear regression models was significant and valid. Large regression sum of squares (6501.65) in comparison to the residual sum of squares (9.585) indicated that the model accounts for most of variation in the dependent variable. The coefficients b_{0Okc}, b_{1Okc}, b_{2Okc} and b_{3Okc} shown in Table 3 are 35.204, -35.079, 0.931 and 1.796 respectively; and the results of the *t*- test indicated that regression coefficients b_{1Okc}, b_{2Okc} and b_{3Okc} were statistically significant and not equal to zero (as given by hypothesis ii) at 0.025 level of significance and 11 degrees of freedom (table t-value=$t_{0.025}$, 11 = 2.201) (*Neave, 1978*). Therefore, the regression equation of melting rate of iron in kg/min. can be given by equation 8. It should be noted that the assumptions made were valid for this model with respect to multi co-linearity and residuals' distribution. As seen from Table 3, the condition indexes value of 4.332, 118.346 and 566.218 are for P, T and F respectively. From Table 3 the predicted value of mean was 4.697 kg/min with standard deviation of 2.431 kg/min implying that control variables were independent. The variance inflation factor *VIF* of 1.004 indicated that multi co-linearity was not a problem in this application (i.e. *VIF* < 4) (*Neave, 1978*), which clearly demonstrated that air pressure; melting time and fuel consumed were not significantly interacting factors.

$$Exp(\dot{M}_4 / P, T, F) = 35.204 - 35.079P + 0.931T + 1.796F \qquad (8)$$

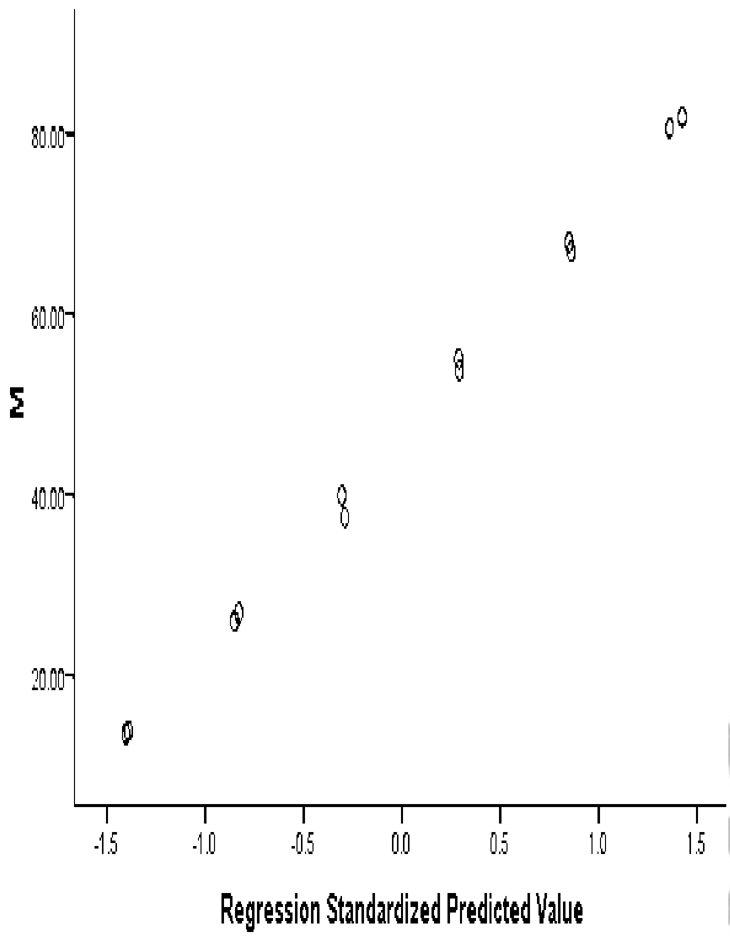

Figure 1: Scatter Plot for the Model

5.0 Conclusion

Multiple linear regression Model was formulated to establish the relationship between air blast pressure, melting time, fuel consumed and iron melting rate of an hybrid fuel-fired cupola furnace. The significance of the relationship between air blast pressure, melting time, fuel consumed and iron melting rate was established. The model summary gave a computed value for the R^2 as 0.999, thus indicating that about 99.9 % of the variation in melting rate could be accounted for by the control variables.

The coefficients b_{0Okc}, b_{1Okc}, b_{2Okc} and b_{3Okc} shown in Table 3 are 35.204, -35.079, 0.931 and 1.796 respectively; and the results of the *t*- test indicated that regression coefficients b_{1Okc}, b_{2Okc}

and b_{3Okc} were statistically significant and not equal to zero (as given by hypothesis ii) at 0.025 level of significance and 11 degrees of freedom (table t-value=$t_{0.025}$, 11 = 2.201). Also in testing hypothesis I, since no value of the regression coefficients for all the independent variables (P, T and F) was equal to zero, the null hypothesis was rejected and the alternative accepted for all the independent variables. The average variance inflation factor *VIF* of 1.004 indicated that multi co-linearity was not a problem in this application (i.e. $VIF < 4$).

The regression model developed in this work can effectively estimate the melting rate based on Air blast pressure; Melting time and Fuel consumption. The model equation when used to develop a computer software will help energy and foundry managers to significantly monitor and improve on the melting rate of a hybrid fuel-fired cupola furnace which may in turn reduce the energy consumed in iron melting.

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