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Plasma Gasification Process: Modelling and Regression Analysis of Experimental Data

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ABSTRACT

Several nations has expressed their interest into plasma gasification as an approach to waste management. Numerous companies have developed the plasma gasification plants in order to exploit the maximize energy and recovery of slags from waste with the help of plasma gasification furnace. In this paper the research was intended to focus on the regression analysis and optimization of data in order to correlate with the experimental data obtained from the plasma gasification. The study was segregated into two different types, the first part was the regression analysis of experimental data with the help of three regression analysis data software's, Minitab, Microsoft excel, Ncss data software. And the other part was the optimization of the data. In this paper the applicability and the comparative effectiveness of regression analysis with different regression analysis data software's have been investigated. And the promising results were obtained by regression analysis which are well correlate with the Empirical data.

Keywords:— *regression, Minitab, Ncss, analysis*

I. INTRODUCTION

Plasma furnace technology has been used in various fields for decades and it has accomplished on an industrial scale in many applications [1-2]. Tremendous efforts are resulting in order to solve the solid waste challenges. After practiced half of the century operationally and technically plasma gasification technology has achieved preference for disposal of solid waste. Plasma is an ionized form of gas, electrically conductive and exist in nature [2 -5]. When dc current passed in between two electrodes with the presence of working gas such as helium, argon and molecules distorted from electrons and ionizes gas obtained. It creates extremely high temperature in plasma furnace which 7000° C -10000°C [5-7]. Plasma furnace converts the carbon-based waste into syngas, synthesis gas. Syngas is combination of hydrogen and carbon mono oxide gas. After conversion the organic waste, Gas turbines converts the green fuel into electricity, slag formation, and in steam. Plasma torch can easily controlled with different temperature parameters in plasma furnace. Plasma furnace operates on high electric temperature that's makes it's more costly. Therefore it's necessary to design plasma furnace less costly and efficient for gasification system [8-9].

Plasma gasification section: plasma torch, gas fillers, heat exchangers, slag handling equipment, Feedstock [10]. As solid waste

enters into plasma chamber, extreme temperature of plasma breakdown it and reduced to a melted slag. Collection of slag at bottom is done by periodically in reactor and Melted slag can be transferred into patterns to create pavement bricks, granules, roads. And finally its turns out into syngas, after traces of pollutants, cleansing process, it can be transferred into gas engine [11]. Plasma gasification entirely monitored with different parameters feed rate, temperature, power. Figure 1 shows the demonstration of plasma gasification [12].

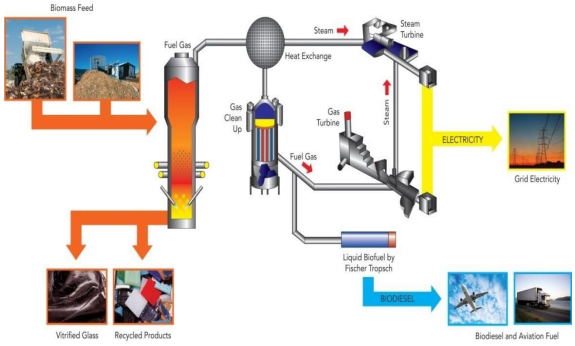

***Figure** 1: Demonstration of Plasma Gasification Process*

II. Experiment Setup and Data Collection

The established plasma reactor model is a non-transferred arc Dc plasma operates in an adiabatic surroundings or in a closed chamber. This model was based on non-stoichiometric chemical symmetry. The model was only used to enhance the series of feedstock in plasma gasification, which are resulting in gas composition, progression in competence. It shows that for the production of high amount of syngas, the feedstock should be high rich in calorific value. As well as feedstock doesn't contain moisture content otherwise it will effect on process efficiency [13]. This experimental data shows the quality of disposal hazardous waste as in high quality syngas such as Rtc coal, tire, and msw. Plasma gasification is a feasible superior for retrieval of materials from solid waste. Which helps out to design the plasma gasification plant and its potential to use different feedstock for syngas. The study shows the performance analysis in order to maximize the production of syngas with different feedstocks. Which makes it's a viable option to analysis the co-relation of independent variables with dependent variable, we put the regression analysis in order to correlate with dependent variable. Performance analysis of different feedstock with the given table in below section, table [1] it's a data for developing regression models-[14]

III. Modelling of Plasma Gasification Parameters – Regression Analysis

Statistical methods likes linear regression least Sq. methods etc. Where regression analysis estimates the correlation in between variables. It helps to understand the relationship in among dependent variables and independent variables. Typically it shows that when variables change takes place with independent variable then dependent variables varies accordingly, while some of independent variables may be fix. It also correlate causal relationship with among variables. In order to obtain the most precise demonstration of physical situation, regression analysis helps to build the realistic model by analysis the experimental data. As given above table shows different Parameters, firstly we include Minitab for regression analysis accordingly;

Minitab

Firstly plywood considered as dependent variable while others are independent variables in order to correlate each independent variable value. Regression analysis estimates the probability of analysis factor in Minitab by given steps accordingly.

Table 1. Data for Developing Regression Model

SNo	Syngas	RTC COAL	TIRE	MSW	ALGAE	TREATED WOOD	UNTRE-AATED WOOD	PINE NEE-DLES	PLYWOOD
1	H_2	50.28	54.69	43.5	31.78	29.64	26.69	28.63	22.68
2	CO	40.89	34.42	34.5	30.47	38.39	36.18	37.34	36.45
3	CO_2	0.05	0.01	0.03	0.04	0.05	0.6	0.81	0.65
4	H_2O	0.72	0.39	16.22	16.18	7.76	10.87	6.28	5.31
5	CH_4	0.01	0.05	0.01	0	0	0	0	0
6	H_2S	0.2	0.28	0.09	0.1	0.03	0.02	0	0
7	N_2	7.83	0.07	5.63	21.42	24.12	25.64	26.93	34.9
8	HCN	0	0	0	0	0.01	0	0	0
9	S	0	0	0	0	0	0	0	0
10	SO_2	0	0	0	0	0	0	0	0
11	COS	0.01	0.01	0	0	0	0	0	0
12	NH_3	0	0	0	0	0	0	0	0
13	C_2H_2	0	0	0	0	0	0	0	0
14	C (solid)	0	10.09	0	0	0	0	0	0
15	Syngas LHV	15.94	21.01	13.44	8.99	9.23	8.31	8.71	7.28
16	Syngas HHV	17.43	23.22	14.71	9.76	9.89	8.89	9.34	7.74
17	Feedstock flow	1	1	1	1	1	1	1	1
18	Plasma gas flow	1.31	0.74	0.36	0.74	0.78	0.85	0.89	1.38
19	Steam ratio	0.7	1	0.56	0.1	0.03	0	0	0
20	Torch power	16.65	11.71	4.06	4.95	4.84	4.84	5.07	7.84
21	Outlet temp.	1264	1270	1267	1267	1258	1260	1257	1256
22	Efficiency (%)	42.1	43	43.3	38.27	46.2	43.5	47	40.51

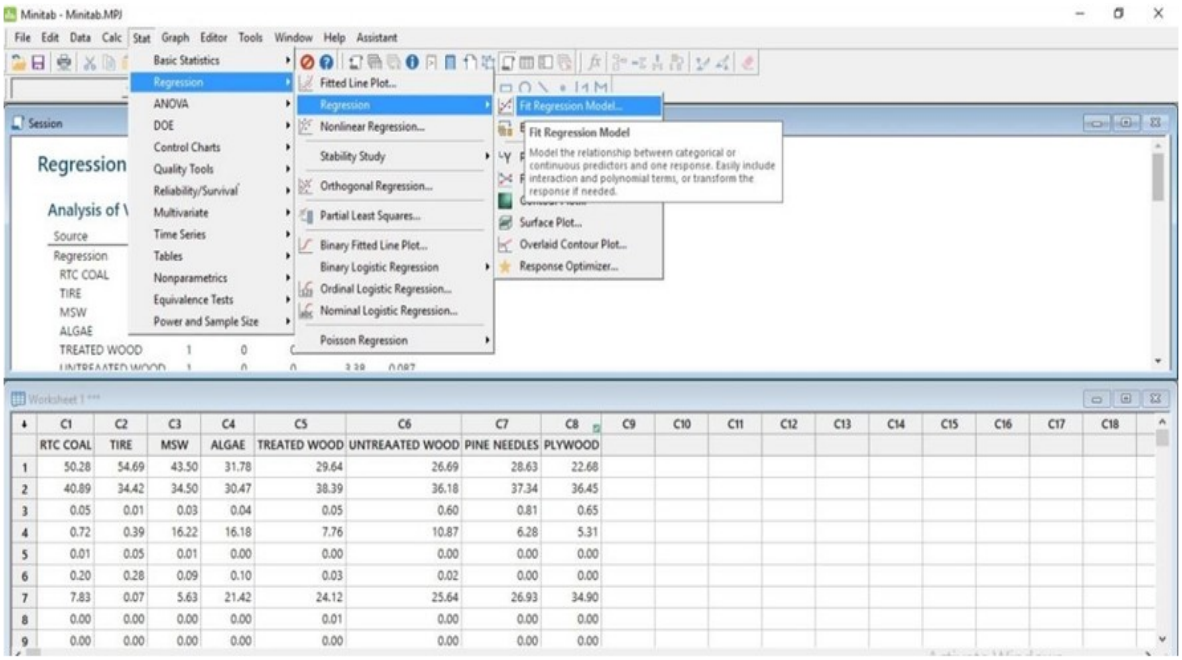

Figure 2. Steps for Regression Analysis in Minitab

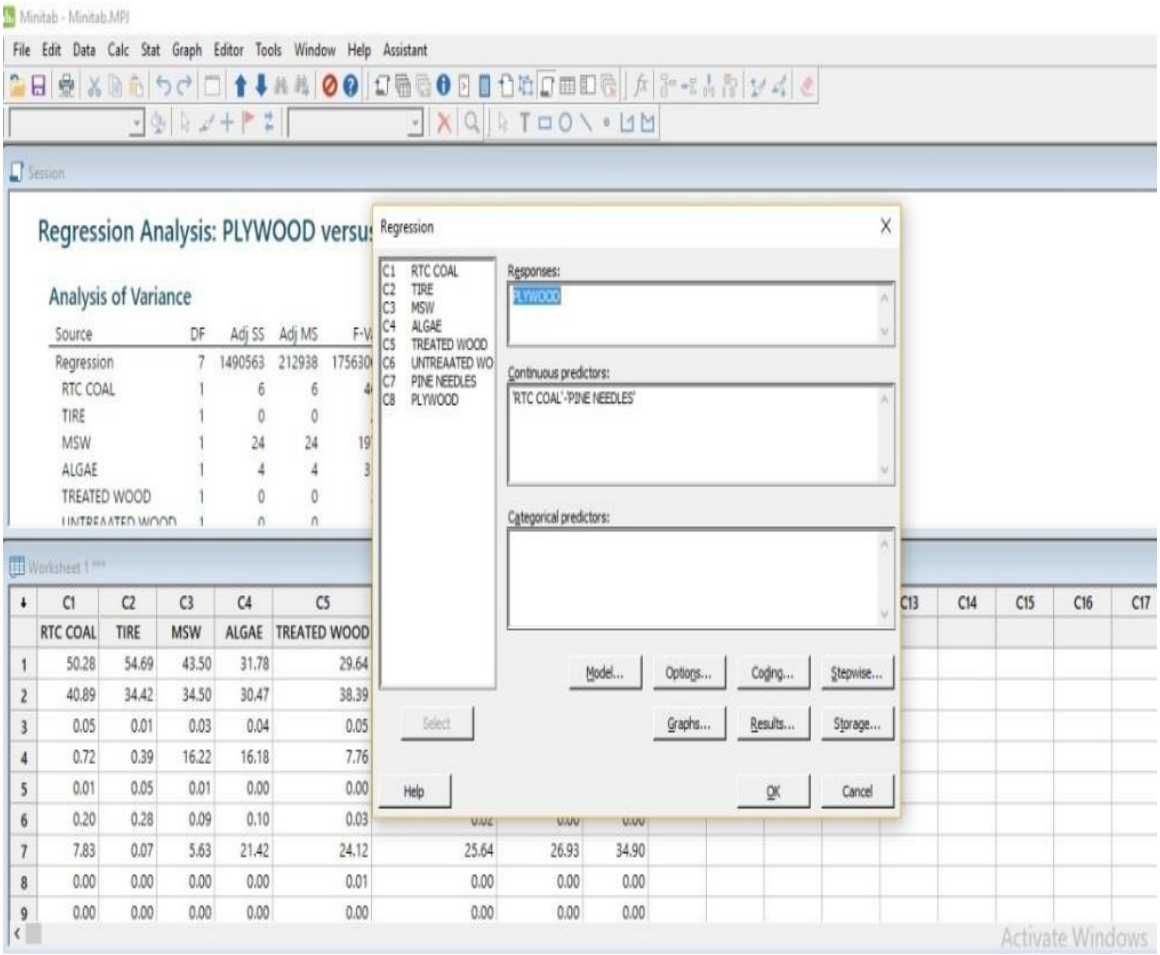

Figure 3: Selection of Parameters in Minitab

As the steps take place in Minitab for regression data, it automatically generated the estimated equation by applying statistical techniques which is shown in equation form, by solving estimates equation.

Regression Equation

= 0.0170 + 0.2185 RTC Coal + 0.0460 Tire - 0.9195 MSW Plywood + 0.652 Algae + 0.752 Treated Wood + 0.501 Untreaated Wood - 0.253 Pine Needles

Table 2. Observed Value, Variance, Percentile Variance

s.no	Y predicted value	Y* experimental value	Variance (Y*-Y)	Percentile variance
Y1	22.65	22.68	0.03	0.13%
Y2	36.22	36.45	0.23	0.63%
Y3	0.16	0.65	0.49	75.38%
Y4	5.51	5.31	-0.2	-3.76%
Y5	0.01	0	-0.01	-
Y6	0.08	0	-0.08	-
Y7	34.69	34.9	0.21	0.60%
Y8	0.02	0	-0.02	-
Y9	0.017	0	-0.017	-
Y10	0.017	0	-0.017	-
Y11	0.019	0	-0.019	-
Y12	0.017	0	-0.017	-
Y13	0.017	0	-0.017	-
Y14	0.48	0	-0.048	-
Y15	6.8	7.28	0.48	6.5%
Y16	7.2	7.74	0.54	6.9%
Y17	1.014	1	-0.014	-1.4%
Y18	1.15	1.38	0.23	16.6%
Y19	-0.21	0	0.21	-
Y20	8.4	7.84	-0.56	-7.14%
Y21	1254.9	1256	1.1	0.08%
Y22	40.97	40.51	-0.46	-1.13%

Mean variance - (Y*-Y) = 0.092

Mean percentile variance is = 4.24%

The mean variance and % variance above calculated and predicted value approximately lies in between the mean percentile value which should not be more or less than 5%. So it's well correlate with empirical data.

Graphs plot-

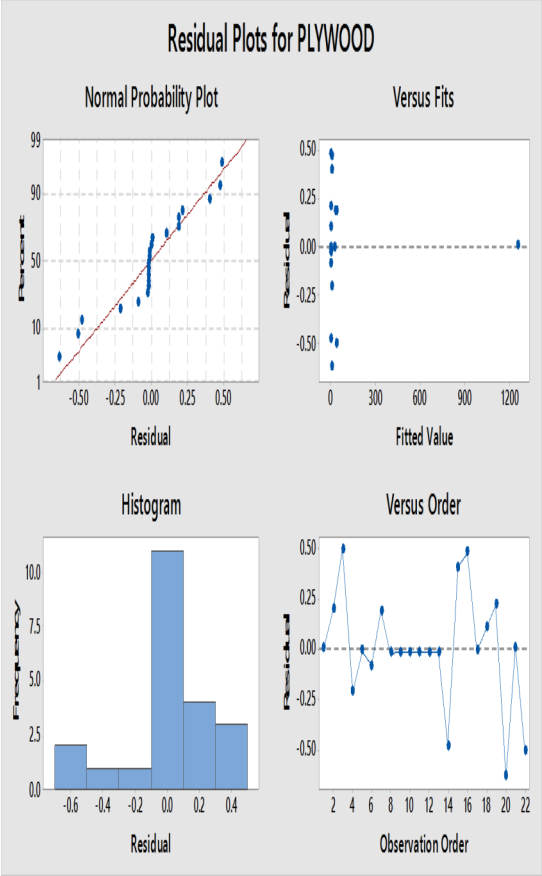

Figure 4: Graph of residual with dependent variables, observation.

Microsoft excel

Regression analysis in excel consist accordingly by choosing dependent and independent variables values to correlate each other. Further steps for regression analysis in excel as shown in figure 5.

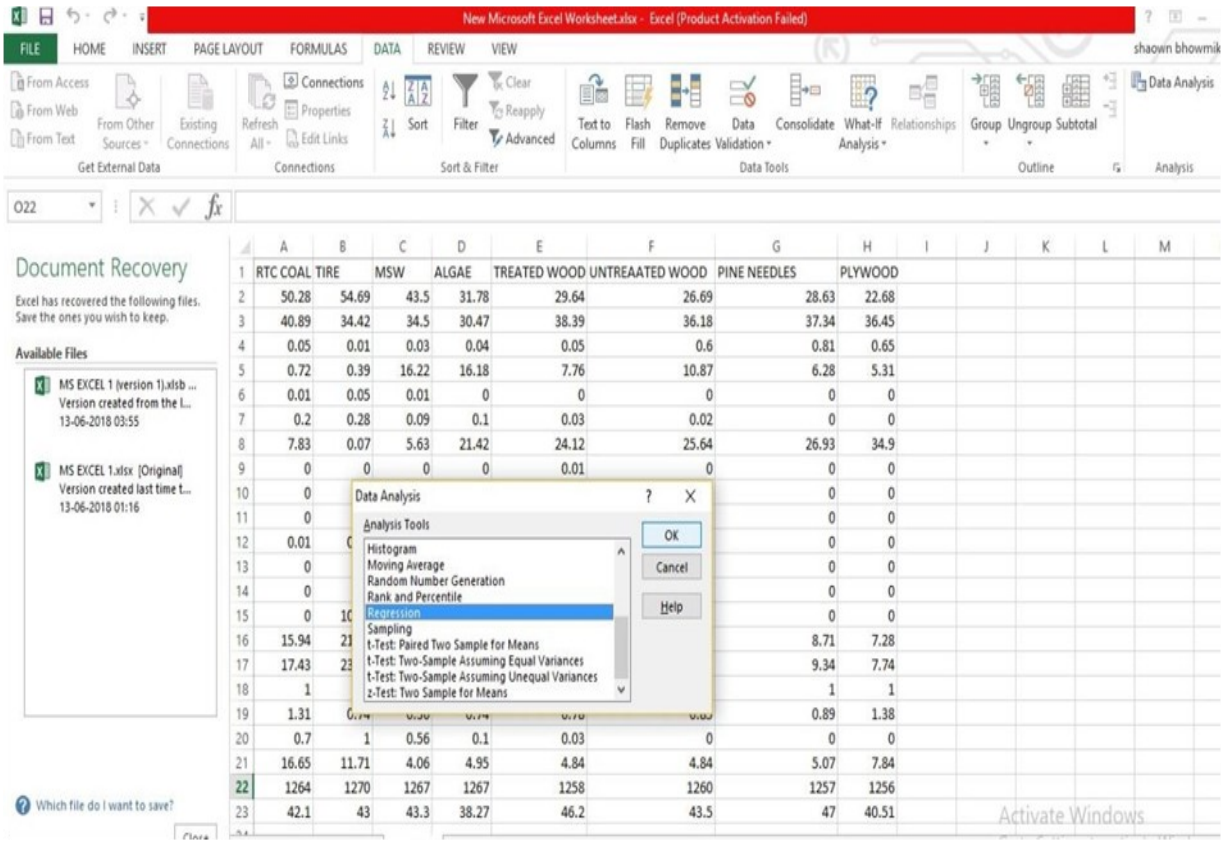

Figure 5: Selection of Regression in Microsoft excel

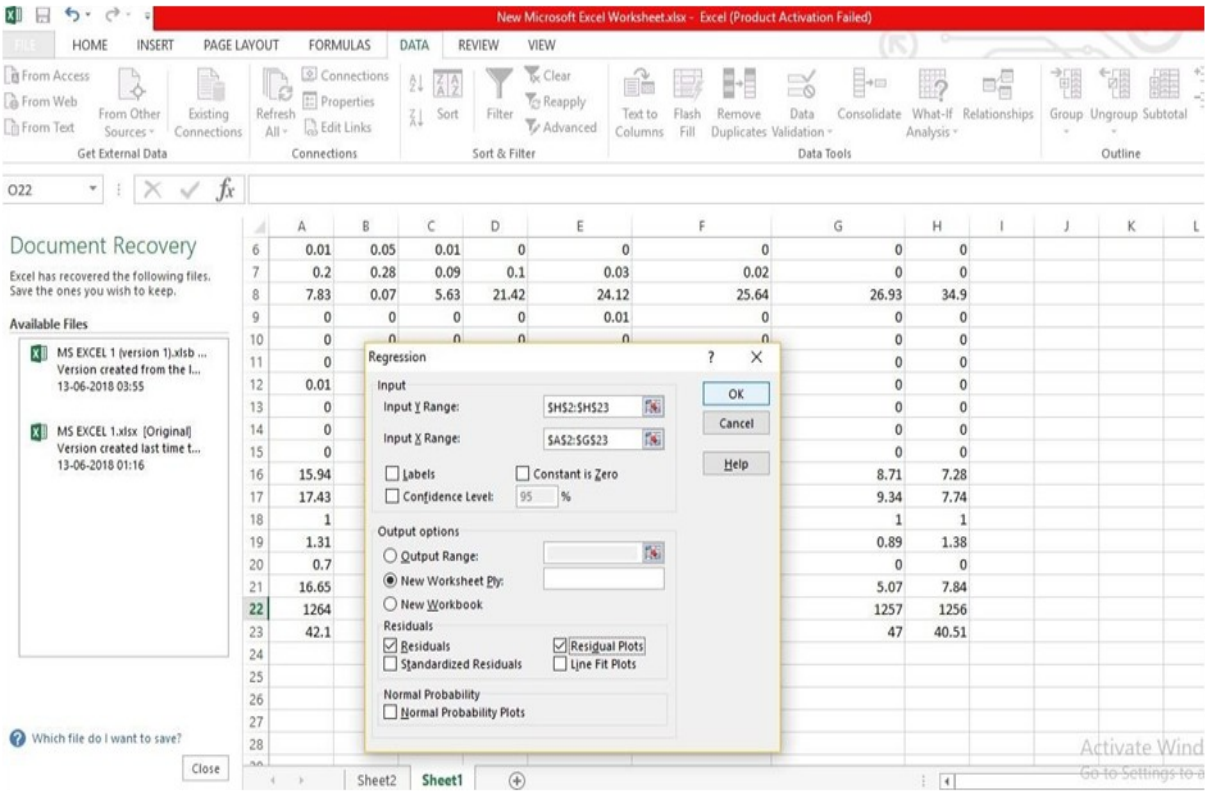

Figure 6. Selection of Parameters Variables in Excel Sheet.

In excel sheet regression analysis calculated the estimated equation statistically or periodically by choosing dependent variables. It generates the whole predicted value with residual statistically. As below table 3.

Shows the comparison in between observed value and experimental value.

Table 3. Excel Regression Observed Values With Dependent Variables

s.no	Y observed	Y* experimen-tal	Variance (Y*-Y)	Percen-tile vari-ance
1	22.68	22.68	-0.001	-0.005%
2	36.25	36.45	0.19	0.52%
3	0.16	0.65	0.48	75.28%
4	5.52	5.31	-0.21	-4.06%
5	0.012	0.00	-0.01	-
6	0.08	0.00	-0.08	-
7	34.71	34.90	0.18	0.53%
8	0.02	0.00	-0.02	-
9	0.01	0.00	-0.01	-
10	0.01	0.00	-0.01	-
11	0.01	0.00	-0.01	-
12	0.01	0.00	-0.01	-
13	0.01	0.00	-0.01	-
14	0.48	0.00	-0.48	-
15	6.87	7.28	0.40	5.53%
16	7.26	7.74	0.47	6.11%
17	1.01	1.00	-0.014	-1.47%
18	1.27	1.38	0.10	7.48%
19	-0.21	0.00	0.21	-
20	8.47	7.84	-0.63	-8.08%
21	1255.99	1256	0.006	0.00%
22	41.01	40.51	-0.505	-1.24%

Mean variance is = 1.07

Mean percentile variance = 3.18%

Therefore the observed value approx. lies in the frame of mean percentile variance which is less than 5%. It's well correlate with empirical data.

Graphs-

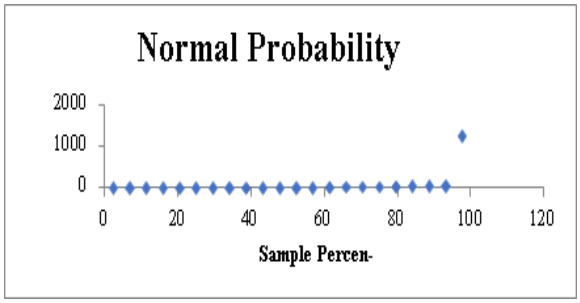

Figure 7. Normal Probability Graph with Residual

Ncss Regression Analysis

Ncss is commonly known for its statistical techniques like regression modelling, linear regression analysis, multiple regression and so on. Steps take out to perform in ncss regression analysis are shown in figure 8.

Multiple regression analysis in Ncss software predicts the estimated equation which well suited to the results of empirical data.

Y =

0.0169576416412696 + 0.218517227122717 * C1 + 0.0459556484477427 * C2 - 0.919454227455458 * C3

+ 0.651788087970 97 * C4 + 0.752263695608535 * C5 + 0.501393234438522 * C6 - 0.252635489239979 * C7

In equation variables takes place accordingly so by following the equation with predicted values proceeds.

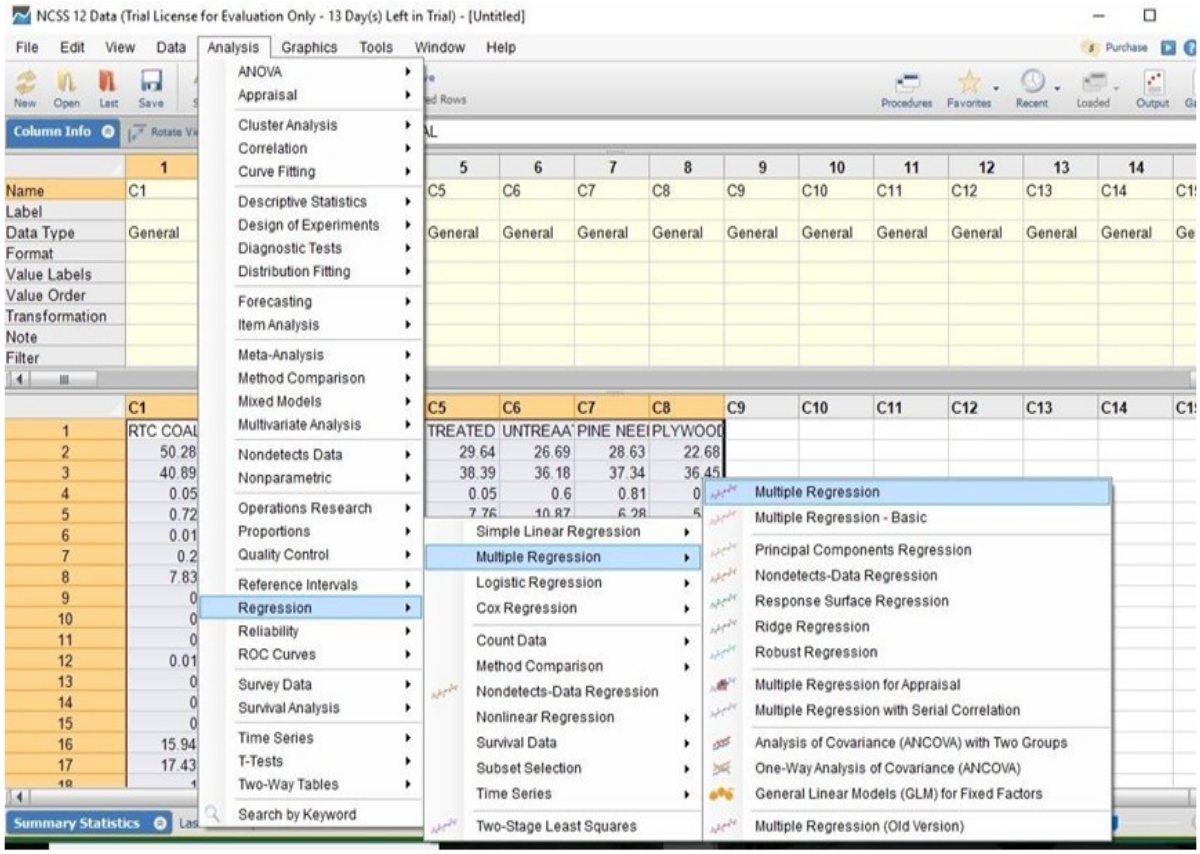

Figure 8. Ncss Selection of Multiple Regression Analysis.

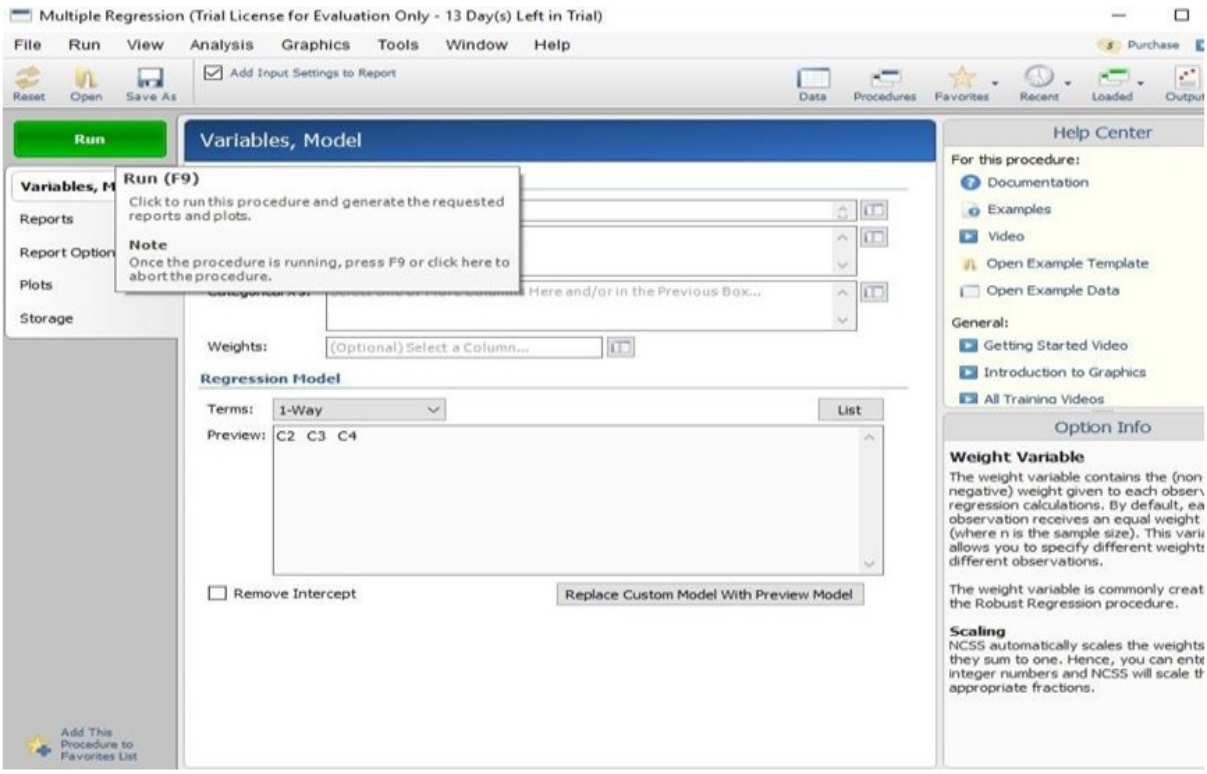

Figure 9. Selection of Dependent and Independent Variables.

Table 4. Predicted Values in Comparison With Actual Values, Variance.

s.no	Y observed	Y* experimental	Variance (y*-y)	Percentile variance
1	22.681	22.68	-0.001	-0.005%
2	36.25	36.45	0.19	0.52%
3	0.16	0.65	0.48	75.28%
4	5.25	5.31	-0.21	-4.06%
5	0.012	0	-0.01	-
6	0.08	0	-0.08	-
7	34.71	34.9	0.18	0.53%
8	0.02	0	-0.024	-
9	0.01	0	-0.016	-
10	0.01	0	-0.016	-
11	0.01	0	-0.48	-
12	0.01	0	0.40	-
13	0.01	0	0.47	-
14	0.48	0	-0.01	-
15	6.87	7.28	0.10	5.53%
16	7.26	7.74	0.21	6.11%
17	1.01	1	-0.63	-1.4%
18	1.27	1.38	0.00	7.4%
19	-0.21	0	-0.50	-
20	8.4	7.84	-0.63	-8.0%
21	1255.9	1256	0.006	0.00%
22	41.01	40.51	-0.50	-1.2%

Mean variance = -0.0690

Mean percentile variation = 3.66%

Ncss regression analysis values shows that its mean percentile values approximately suit with actual values which is less than 5%. So it's well correlate with empirical values.

Graph-

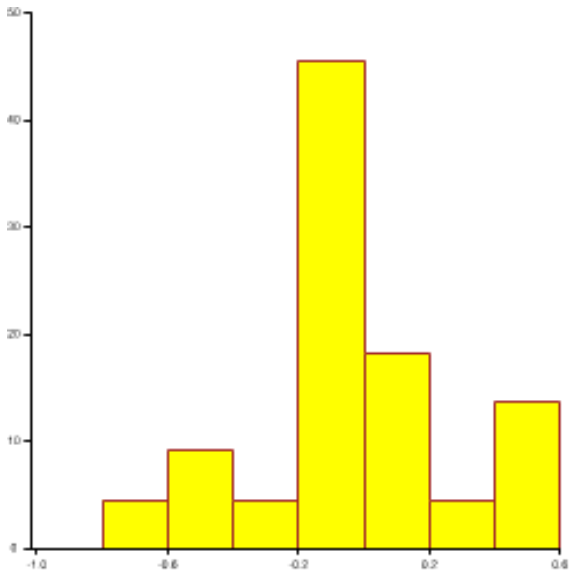

Figure 10. Residual plot with mean percentile values

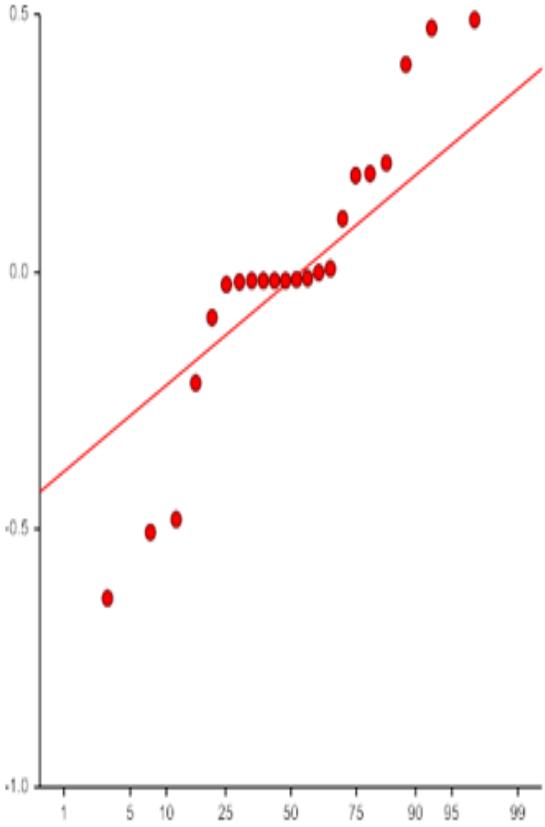

Figure 11: Normal probability plot with residual

IV. RESULTS AND DISCUSSION

Comparison in between all regression analysis software values or predicted values as shown in table 5.

Table 5. Comparison of All Regression Analysis Data.

s.n	Actual value (Y)*	Minitab observed values			Microsoft excel values			Ncss software values		
	Dependent Variable	Predicted (Y)	variance	% variance	Predicted (Y)	variance	% variance	Predicted (Y)	variance	% variance
1	22.68	22.65	0.03	0.13	22.68	-0.001	-0.005	22.68	-0.001	-0.005
2	36.45	36.22	0.23	0.61	36.45	0.19	0.52	36.25	0.19	0.52
3	0.65	0.16	0.49	7.38	0.16	0.48	75.2	0.16	0.48	75.28
4	5.31	5.51	-0.2	-3.76	5.52	-0.21	-4.06	5.25	-0.21	-4.06
5	0	0.01	-0.01	-	0.012	-0.01	-	0.01	-0.01	-
6	0	0.08	-0.08	-	0.018	-0.08	-	0.08	-0.08	-
7	34.9	34.69	0.21	0.60	34.71	0.18	0.53	34.71	0.18	0.53
8	0	0.02	-0.02	-	0.02	-0.02	-	0.02	-0.02	-
9	0	0.017	-0.01	-	0.01	-0.01	-	0.01	-0.01	-
10	0	0.017	-0.01	-	0.01	-0.01	-	0.01	-0.01	-
11	0	0.019	-0.01	-	0.01	-0.01	-	0.01	-0.48	-
12	0	0.017	-0.01	-	0.01	-0.01	-	0.01	0.40	-
13	0	0.017	-0.01	-	0.01	-0.01	-	0.01	0.47	-
14	0	0.48	-0.04	-	0.48	-0.48	-	0.48	-0.01	-
15	7.28	6.8	0.48	6.5	6.87	0.40	5.53			
16	7.74	7.2	0.54	6.9	7.26	0.47	6.11	7.26	0.21	6.11
17	1	1.01	-0.01	-1.4	1.01	-0.014	-1.47	1.01	-0.63	-1.4
18	1.38	1.15	0.23	16.6	1.27	0.10	7.48	1.27	0.00	7.4
19	0	-0.21	0.21	-	-0.21	0.21	-	-0.21	-0.50	-
20	7.84	8.4	-0.56	-7.14	8.47	-0.63	-8.08	8.4	-0.63	-8.0
21	1256	1254	1.1	0.08	1255	0.006	0.00	1255	0.006	0.00
22	40.51	40.9	-0.46	-1.13	41.01	-0.505	-1.24	41.01	-0.50	-1.2

Table 6. Optimization of Mean Percentile Value.

S.No	MINITAB	MICROSOFT EXCEL	NCSS
1	4.24 %	3.18 %	3.66 %
Hence, mean percentile value is less in Microsoft excel. Which is 3.18% so approx. observed values with dependent variables comes in excel which looks relevant to empirical data.			

V. CONCLUSION

On the basis of regression analysis, optimization. It concluded that predicted observation closely comes out under the Microsoft excel, which are well correlated with the empirical data of plasma gasification. Regression analysis closely shares the results obtained by excel sheet in order to know the relationship between variables accordingly.

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