Prediction and Optimization of Production Product

Abstract
In this research, it focused on the prediction and optimization of the production quantity in Innoson Plastic Manufacturing Company, Nnewi, Anambra State, Nigeria. The research method used is the application of factorial design methods to model, analyze and to evaluate the best optimal solutions for the production quantity of extrusion plastic pipes in the aforementioned company. The analysis shows that the parameters used to model the production quantity are significant and the model produced is also significant with its coefficient of determination to be 0.9968. The factorial design method applied shows the optimal solution which revealed that the best quantity of the product that is necessary to produce in any given month is 14414.112units with the optimal desirability of 100%. The tool also shows that the pigment is almost not important in the optimization of the product production quantity due to its insignificant quantity. However, the results further revealed that the industry should be conscious of highly influence input variable during production.
Keywords: Optimization, factorial design, production, plastics, pipes, Desirability

1 Introduction

The production process is concerned with transforming a range of inputs into those outputs. This involves two main sets of resources - the transforming resources, and the transformed resources. The transforming resources include the buildings, machinery, computers, and people that carry out the transforming processes. The transformed resources are the raw materials and components that are transformed into end products. Any production process involves a series of links in a production chain. At each stage value is added in the course of production. Adding value involves making a product more desirable to a consumer so that they will pay more for it. Adding value therefore is not just about manufacturing, but includes the marketing process including advertising, promotion and distribution that make the final product more desirable. It is very important for businesses to identify the processes that add value, so that they can enhance these processes to the ongoing benefit of the business. Production is very critical to economic growth, prosperity and a higher standard of living. It is a catalyst for industrial and economic development. Its satisfy economic want of individual, communities and nations by production of things in workshops by utilizing men, materials, machines, money and methods (Jeffrey, 2012). Essentially, manufacturing can be simply define as value addition processes by which raw materials of low utility and value to its inadequate material properties and poor irregular size, shape and finish are converted into high utility and valued product with definite dimensions, forms, and finish imparting some functional ability by utilizing resources (Jagadeesha, 2016). The resources could be people, machines, computers and/or organized integration of one or more of the above mentioned (Krishna and Bani 1999). To realize higher efficiency, there must be optimal allocation of these resources to activities of production.

The aim of this research work is to predict and to optimize the production quantities of Innoson manufacturing extraction plastic products in Nnewi, Anambra State, Nigeria.

Optimization is finding an alternative with the most cost effective or highest achievable performance under the given constraints, by maximizing desired factors and minimizing undesired ones (LaForge, 1998). The researches on related literatures were also emphasized to express the empirical related works in the research. Christopher (2011), expressed that Manketti oil was used as a feedstock to produce the biodiesel was extracted from manketti nut. An alkali catalyst transesterfication process was adopted. A statistical model was developed to correlate the transesterification process variables to the yield of fatty acid methyl ester (FAME) using a central composite design (CCD) by a response surface methodology. The transesterification process variables were reaction temperature x1, (30°C–65°C), amount of catalyst x2, (0.5–1.5 wt %), amount of methanol in the oil x3, (10–50 wt%), and reaction time (30–90 min). The essential fuel properties such as density, flash point, viscosity, and acid number were measured and compared with other types of biodiesel produced from wild nuts and American Society for Testing and Material (ASTM) standards for biodiesel. From the results, the optimum conditions for the production of FAME obtained were as follows: reaction temperature 55°C, reaction time 53 min, amount of catalyst 1.02 wt%, and amount of methanol in the oil of 32 wt%. The optimum yield of FAME that can be produced was 98.3%. The results show that the important fuel properties of the biodiesel produced in optimum conditions met the biodiesel ASTM standard.

Abdullah (2013), presents an experimental investigation into the effects of using bio-diesel on diesel engine performance and its emissions. The bio-diesel fuels were produced from vegetable oils using the transesterification process with low molecular weight alcohols and sodium hydroxide then tested on a steady state engine test rig using a Euro 4 four cylinder Compression Ignition (CI) engine. Production optimization was achieved by changing the variables which included methanol/oil molar ratio, NaOH catalyst concentration, reaction time, reaction temperature, and rate of mixing to maximize bio-diesel yield. The technique used was the response surface methodology. In addition, a second-order model was developed to predict the bio-diesel yield if the production criteria is known. The model was validated using additional experimental testing. Christopher (2013), studied biodiesel was produced from waste cooking oil (WCO) using calcium oxide (CaO) as a heterogeneous catalyst. The effect of experimental variables such as temperature, reaction time, methanol to oil ratio, and amount of catalyst were investigated. Using a central composite design (CCD) of experiments variables, a mathematical model was developed to correlate the experimental variables to the percentage of biodiesel yield. The model shows optimum conditions for biodiesel production were found as follows: amount of catalyst of 2.75 grams, temperature 73.23 °C, methanol to oil ratio 30.08 wt % and reaction time of 3.86 h. A yield of 85.96 % biodiesel was obtained. The results show that the important fuel properties of the biodiesel produced at optimum conditions met the biodiesel ASTM standard.

In summary, the reviewed literatures have shown that the research area under investigation is new and genuine. The researchers however, proceed with the method used for the analysis of this research.

3 Research Method

The research method used for data analysis is the application of minimum run characterization design method in factorial design. It is a tool in Design Expert software which is used to model, evaluate and analyze the production quantities under study. Data was analyzed by using factorial design method to optimize the actual quantity needed to be produce in the plastic under production using the appropriate input variables over the month in the manufacturing industry.

Table1: Production Variables

Std	Run	Component 1 A:PVC (kg) kg	Component 2 B:Sterbilizer (kg) kg	Component 3 C:Calcium (kg) kg	Component 4 D:Steric (kg) kg	Component 5 E:Titanium (kg) kg	Component 6 F:Pigment (kg) kg	Response 1 Output units
1	1	17101.8	578	310	5	5	0.2	8060
10	2	17048.8	578	310	58	5	0.2	7600
8	3	17053.4	578	310	58	0.4	0.2	10822
3	4	17352	52	535.6	58	0.4	3	6020
12	5	14414.8	52	3470	58	5	0.2	2340
7	6	13891.6	578	3470	58	0.4	2	6510
5	7	17100	578	310	5	5	2	14310
6	8	17106.4	578	310	5	0.4	0.2	6820
11	9	14472.4	52	3470	5	0.3	0.2	7750
2	10	17352	52	531	58	5	2	4560
4	11	13891.6	578	3470	58	0.4	2	1280
9	12	13940	578	3470	5	5	2	2860

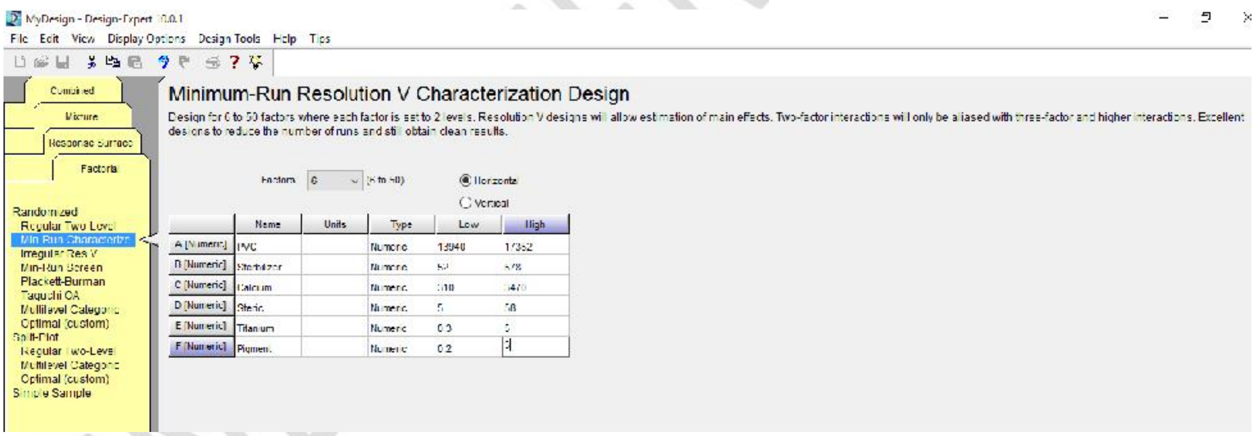

Figure 1: Variables of the Input Parameters

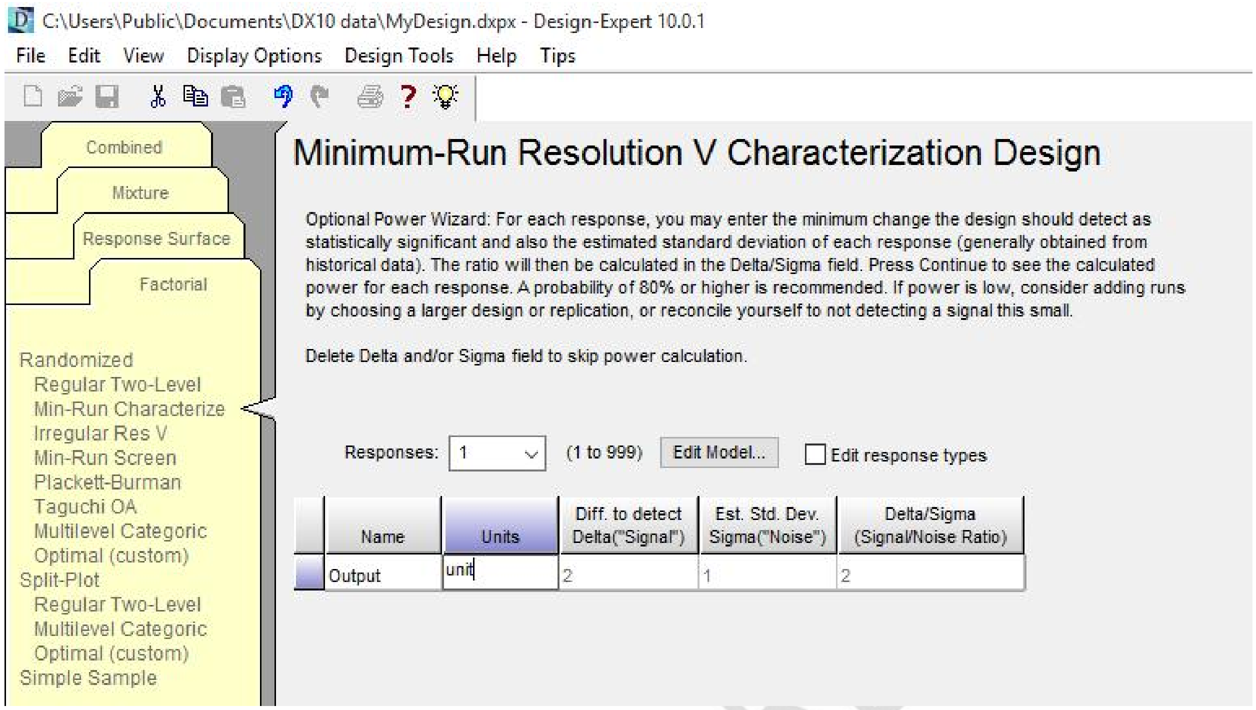

Figure 2: Variables of the Output Parameters

Table 2: ANOVA for selected factorial model
Analysis of variance table [Partial sum of squares - Type III]

Source	**Sum of Squares**	**df**	**Mean Square**	**F Value**	**p-value Prob > F**	
Model	6113.71	9	679.30	68.99	0.0144	significant
A-PVC	*12.75*	*1*	*12.75*	*1.29*	*0.3732*	
B-Sterbilizer	*73.19*	*1*	*73.19*	*7.43*	*0.1123*	
C-Calcium	*10.19*	*1*	*10.19*	*1.03*	*0.4161*	
D-Steric	*8.44*	*1*	*8.44*	*0.86*	*0.4522*	
E-Titanium	*1263.03*	*1*	*1263.03*	*128.27*	*0.0077*	
AB	*534.01*	*1*	*534.01*	*54.23*	*0.0179*	
BD	*551.92*	*1*	*551.92*	*56.05*	*0.0174*	
BE	*132.07*	*1*	*132.07*	*13.41*	*0.0671*	
CD	*44.34*	*1*	*44.34*	*4.50*	*0.1679*	
Residual	19.69	2	9.85			
Cor Total	6133.40	11				

The Model F-value of 68.99 implies the model is significant. There is only a 1.44% chance that an F-value this large could occur due to noise. Values of "Prob > F" less than 0.0500 indicate model terms are significant. In this case E, AB, BD are significant model terms.

Values greater than 0.1000 indicate the model terms are not significant. If there are many insignificant model terms (not counting those required to support hierarchy), model reduction may improve your model.

Table 3: Model Summary Analysis

Std. Dev.	3.14	R-Squared	0.9968
Mean	77.89	Adj R-Squared	0.9823
C.V. %	4.03	Pred R-Squared	N/A
PRESS	N/A	Adeq Precision	29.271
-2 Log Likelihood	40.00	BIC	64.85
		AICc	280.00

The R-Squared is 0.9968 and the adjusted R-Squared is 0.9823. The "Pred R-Squared" of is nil however, the difference is less than 0.2. This indicates a positive effect or a possibility of achieving the results with the developed model and data. Case(s) with leverage of 1.0000: Pred R-Squared and PRESS statistic not defined. Adeq Precision measures the signal to noise ratio. A ratio greater than 4 is desirable. The ratio of 29.271 indicates an adequate signal. This model can be used to navigate the design space.

Final Equation in Terms of Actual Factors:

Sqrt(Output) =
-51.37221
+5.26319E-003 * PVC
+0.41796 * Sterbilizer
+9.81856E-004 * Calcium
+0.69827 * Steric
+11.38566 * Titanium
-1.97956E-005 * PVC * Sterbilizer
-1.90140E-003 * Sterbilizer * Steric
-0.012692 * Sterbilizer * Titanium
-7.95149E-005 * Calcium * Steric

The equation in terms of actual factors can be used to make predictions about the response for given levels of each factor. Here, the levels should be specified in the original units for each factor. This equation should not be used to determine the relative impact of each factor because the coefficients are scaled to accommodate the units of each factor and the intercept is not at the center of the design space.

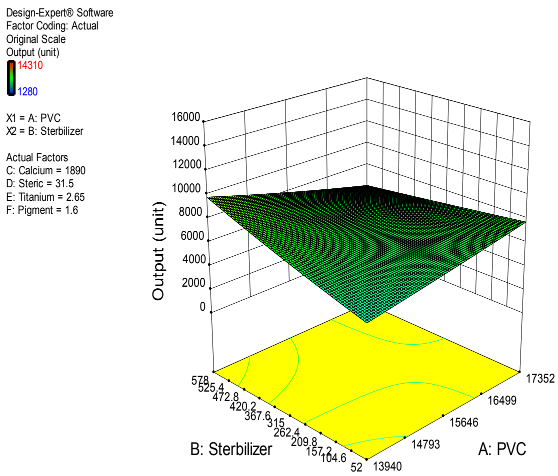

Figure 3a: The 3D Surface Plot for PVC and Stabilizer

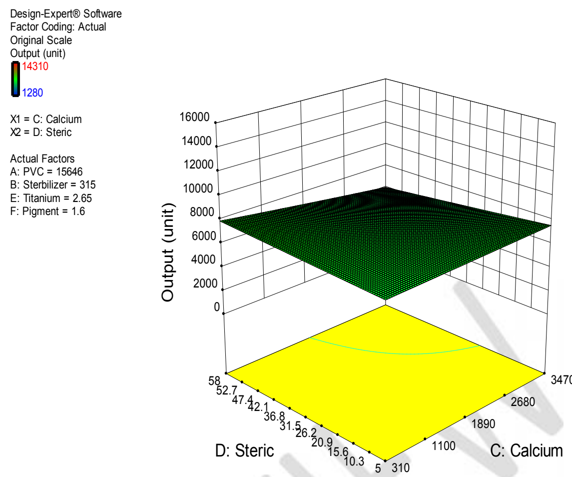

Figure 3b: The 3D Surface Plot for Calcium and Steric

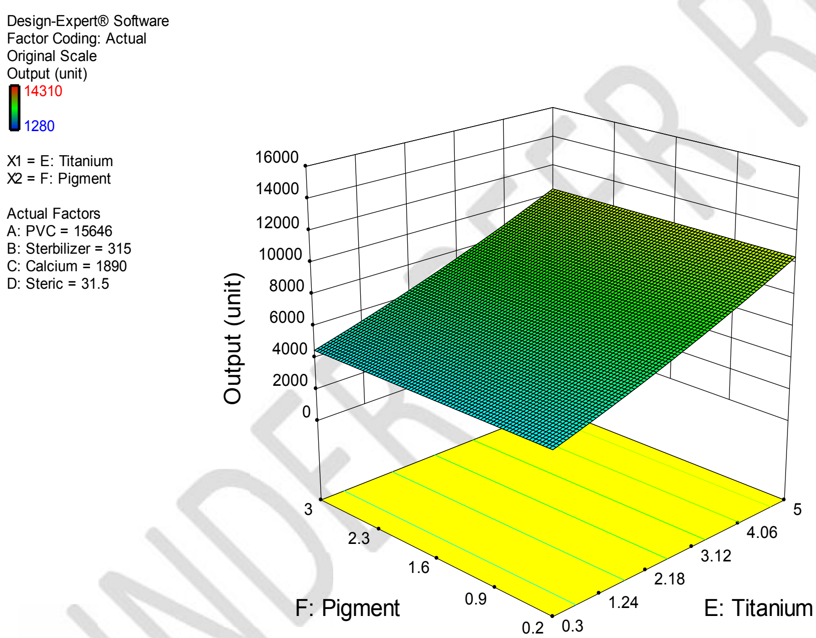

Figure 3c: The 3D Surface Plot for Pigment and Titanium

The 3D surface plot shows the effect of the variables in production system. It describes the variations of the input and output parameters in production of plastic extrusion products.

4. **Optimization of the solutions**

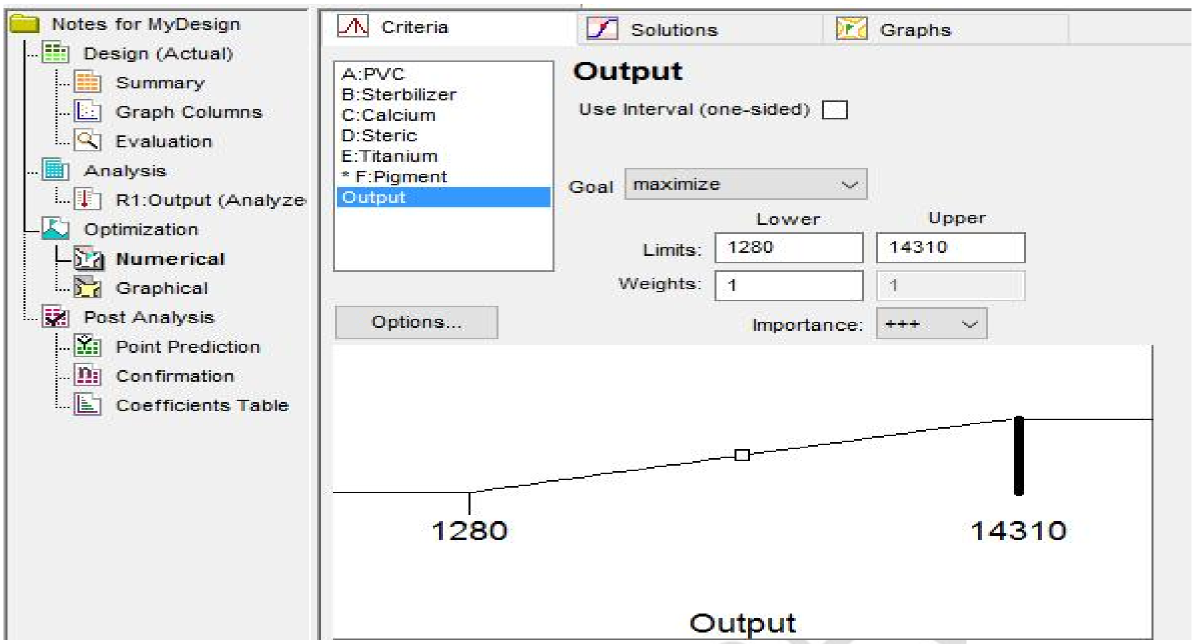

Figure 4: The Criteria for Optimal Solutions

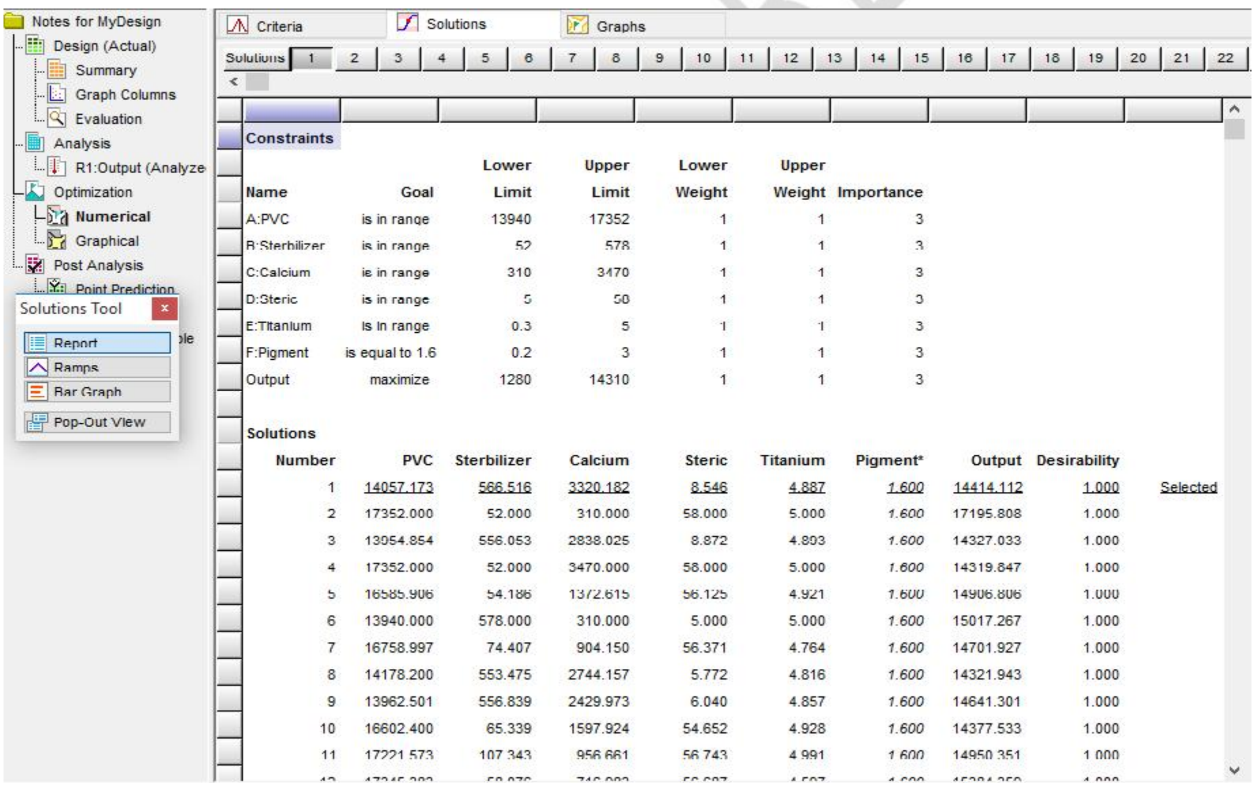

Figure 5: The Results of the Optimal Solutions

In figure 5, the optimization solution report reveals that the model found over a hundred (100) Solutions, but the selected desired solution is the first solution with its desirability of 100% and production output of 14414.112 units of plastic extrusion pipe products. The input parameters with the symbol * has no effect on the optimization results.

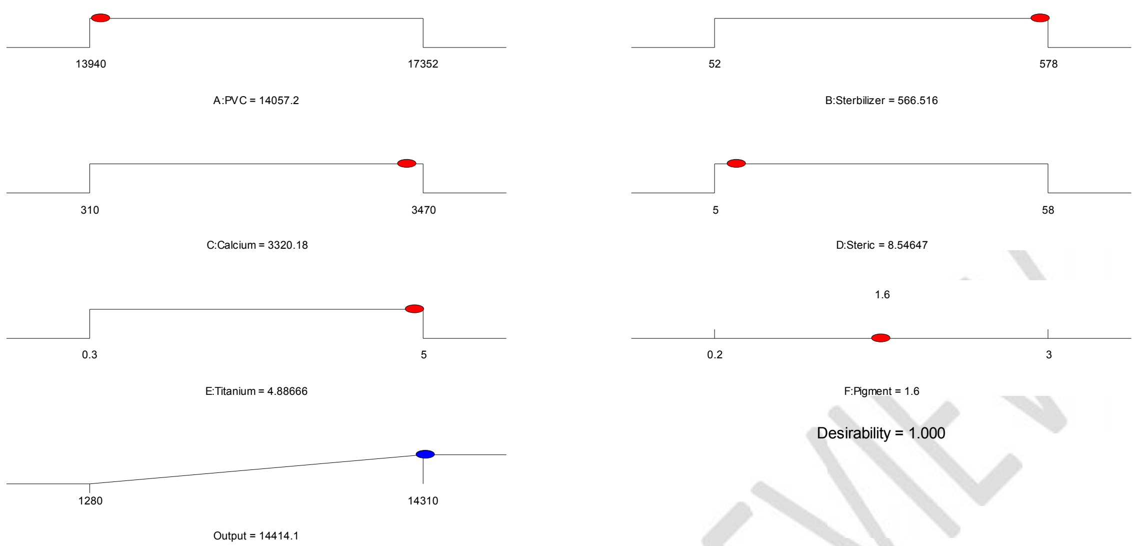

Figure 6: Graphical results of the Optimal Solutions

Figure 6 express the graphical results of the optimal solutions selected as its in table 7 above

Figure 7: Desirability Results of the Parameters

Figure 7 express the rate of desirability of all the variables under investigation. The result shows that calcium is most desired in extrusion plastic pipe production.

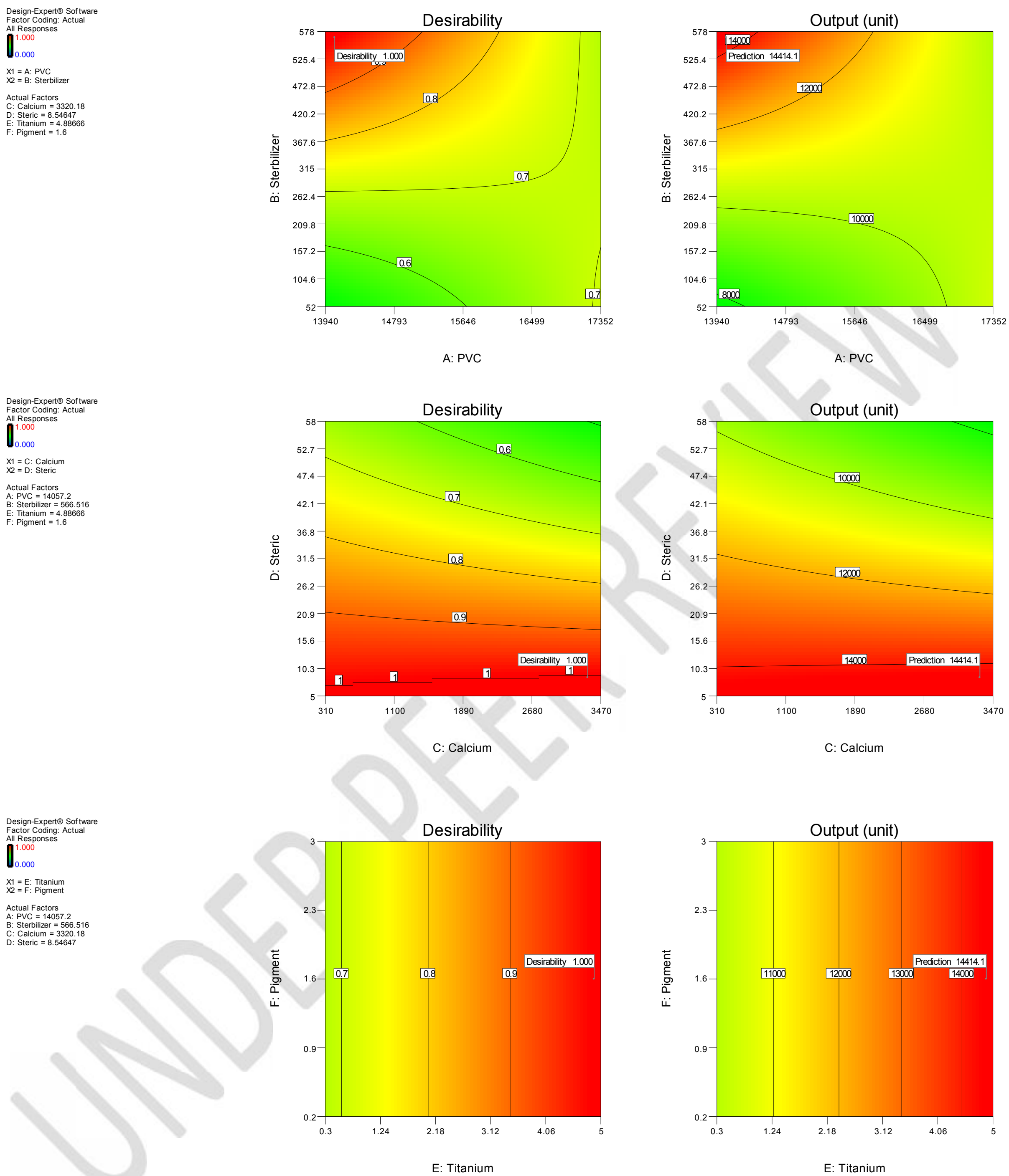

Figure 8: Desirability User defined Solution

Minimum run Characterization design in Factorial design method shows the approximation of the desirability on the optimal solution in the production system. Minimum run Characterization design in Factorial design method shows the approximation of the output on the optimal solution in the production system.

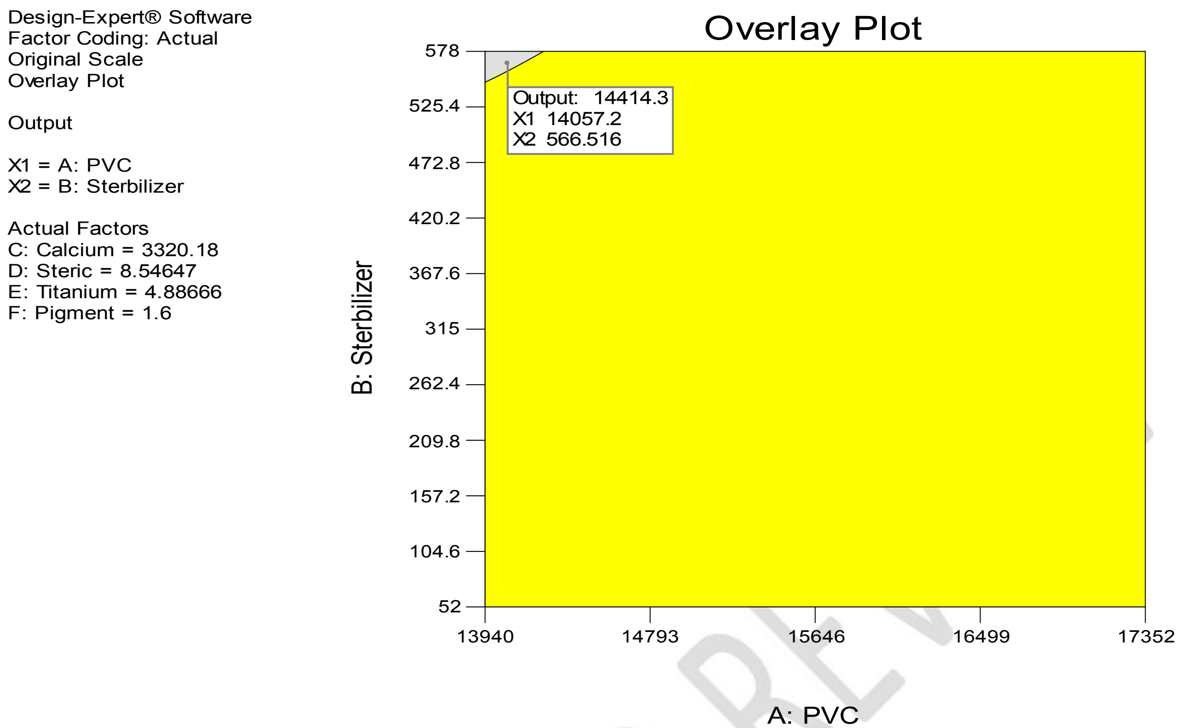

Figure 9: Overlay Plot showing the Predicted Optimal Solutions

The overlay plot in figure 9 shows the optimal solutions of both the input and output parameters in the production variables

Discussion

The results discuss were focused on the evaluation, prediction and optimization of the production quantities, the results, tables and figures developed during the analysis of this research. The data is a combined input of the plastic production raw material and the unit quantity of the finished plastic extrusion pipe produced over any given month. The data was evaluated, analyzed and optimized. The application of analysis of variance (ANOVA) reveals that the variables are significance to model the production variables of the system. However, the coefficient of determination (R-Squared) if the model is 0.9968, while the adjusted R-Squared is 0.9823. The "Pred. R-Squared" of is nil however, the difference is less than 0.2. This indicates a positive effect or a possibility of achieving the results with the developed model and data. The Minimum run Characterization design in Factorial design method analysis shows that sterbilizer is almost not important in the production when compared with other variables. The 3D surface plot shows the effect of the variables in production system.

Finally, the application of the Minimum run Characterization Design in Factorial Design method shows the optimization model that express the optimal solution quantity which is best to produce every month in the aforementioned company is 14414.112 units of plastic extrusion pipes. And the best quantity for the PVC, stabilizer, calcium, steric Acid, titanium and pigment raw material variables to be used are 14057.173kg, 566.516kg, 3320.182kg, 8.546kg, 4.887kg and 1.600kg respectively over the months of production. However, the optimal solutions give a desirability of 1.00 or 100%.

Conclusion

Having revealed the production variables, it is obvious that optimization system is the gate way to ensure the best in production system and in industrialization sectors. The evaluation and analysis of production optimal quantities have revealed that the optimal solution of the system has 100% percent desirability. However, the optimal solution for the production output is 14414.112 units of plastic extrusion pipes. Finally, the results were recommended to the case company, to ensure an efficient and more preferred production in their industry.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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