Global Scientific JOURNALS

GSJ: Volume 6, Issue 3, March 2018, Online: ISSN 2320-9186
www.globalscientificjournal.com

SIMULATION AND OPTIMIZATION OF GASOLINE BLENDING IN A NIGERIAN PETROLEUM REFINING COMPANY.

JOHN T. IMINABO, MISEL IMINABO and ALFRED U. ENYI

Department of Chemical/Petrochemical Engineering, Rivers State University of Science and Technology, Nkpolu, Port Harcourt Nigeria.
**Corresponding author: iminabo.john@ust.edu.ng*

ABSTRACT

Without accurate blending correlation, any attempt to blend different gasoline cuts can be expected to achieve non profitable results. This study focused on the simulation and optimization of the gasoline blending process in a Nigerian Petroleum Refining Company. The gasoline produced by the refinery was analyzed for the purpose of reducing the cost of production using a proper blending method. Linear programming model was developed to determine the production cost of the blend and was solved with MATLAB V7.5 Compiler. Using the model, three (3) different cases were investigated namely Research Octane Number (RON) 89, 91 and 94. The objective function was a cost function which represented the cost of operation for the production of gasoline products. This objective function was minimized subject to a set of constraints which represent the demands for quality and quantity of final gasoline products. The results of testing the model indicate that the solution is a feasible, local optimum solution, and there is good agreement with the demands. The minimized cost based on the model for RON 89, 91 and 94 was found to be $122.31/m^3$, $124.69m^3$ and $122.30/m^3$ respectively which was found to be lower than the current cost of production of $129.06/m^3$, $126.04/m^3$ and $123.74/m^3$ respectively at the same quality and quantity.

Key words: Simulation, Optimization, Gasoline, Research Octane Number

1.0 INTRODUCTION

Moore (2011) defines gasoline blending as the process of combining two or more components of feed stocks, produced by refinery units, together with some proportion of additives to make a mixture to meet certified quality specifications. The purpose of blending in a petroleum refinery is to mix semi-finished products that have been rectified during various manufacturing processes so as to manufacture a product that meets specification. In general, gasolines are blended from several petroleum refinery process streams that are derived by the following methods: direct distillation of crude oil, catalytic and thermal cracking, hydrocracking, catalytic reforming, alkylation, and polymerization. Modern petroleum refining begins with the distillation of crude oil into the following fractions: light naphtha (used as a component of finished gasoline without additional refining), heavy naphtha (catalytically reformed to a higher-octane blending stock), kerosene and light gas-oil (used in the production of kerosene, jet fuel, diesel fuel, and furnace oils), heavy gas-oil (used in heavy diesel fuel, industrial fuel oil, and bunker oil), and reduced crude. The heavy gas-oil and other heavy oils recovered from the reduced crude can be cracked into gasolines (Smith, 2003). The Research Octane Number (RON) or the Motor Octane Number (MON) of an unleaded gasoline is one of the most essential measures of gasoline quality. The RON and the MON of gasoline are measurements of its quality of performance as fuel. An octane number is a number which measures the ability of the gasoline to resist knocking. Knocking occurs when fuel combusts prematurely or explodes in an engine, causing a distinctive noise which resembles knocking. Celik, (2008) studied experimental determination of suitable ethanol–gasoline blend rate at high compression ratio for gasoline engine. Also Diab *et al* (2014) carried out a research on the optimization of motor gasoline using ethanol as a blending component. In their research, ethanol was used as fuel at high compression ratio to improve performance and to reduce emissions and price of gasoline. Despite the importance of gasoline blending, difficulty exists in determining the right quantity & quality of the various blending parts to use in achieving a product of high quality at the lowest possible cost of production. In this work a linear blending problem is used where the objective function is linear and the constraints are also linear. In terms of equations the terms in the said equations should also be linear. Rusin *et al* (1981) stated that for linear blending the octane number of a blend will be equal to the addition of the octane numbers of the components in proportion to their concentrations. The objective is to minimize the cost of operation for gasoline production such that the quality and quantity demands are satisfied. The optimum solution will yield in quality and quantity needed for blend components and optimum value for decision variables. These are also called Targets, which will be sent to the advanced control level for implementation. The optimization model assumes that the qualities of final gasoline products are a linear function of the qualities of the streams sent to the blending unit.

2.0 MATERIALS AND METHODS

2.1 MATERIALS

The quality control department of the Refining Company sampled six (6) different gasoline blending components, namely Straight Run Gasoline (SRG) tank1, Straight Run Naphtha (SRN) tank2, Reformate tank3, Fluid Catalytic Cracking Gasoline (FCCG) tank4, Dimate tank5, and the alkylate tank6 product. MATLAB V7.5 Compiler was used in writing the simulation program.

2.2 METHODS

Gasoline blending involves the mixing of catalytic reformed product, alkylation product, the catalytic cracking product and additives. There are several properties that are important in characterizing automotive gasoline such as Research Octane Number (RON), Reid Vapor Pressure (RVP) etc. This work will be limited to considering the RON. In this work a linear blending problem is used where the objective function is linear and the constraints are also linear. The objective function is a cost function which represents the cost of operation for production of blending components plus the inventory cost. This objective function is minimized subject to a set of constraints which represent the demands for quality and quantity of final gasoline products.

2.2.1 Blending Models

The qualities of the outlet stream of the gasoline blending unit, which is the final gasoline product, are assumed to blend linearly as a function of the quality of the streams sent to the gasoline blending. It is expressed mathematically as follows:

$$ON_{BLEND} = \sum ON_i f_i \quad (1)$$

Where

ON_i The octane number of component i

f_i The volume percent of component i

ON_{BLEND} Blended gasoline

Recall that the assumption of a well stirred tank means that the quality of the effluent is identical to the quality of the material in the tank: that is

$$ON_I = q_{it} \quad (2)$$

$$RON_t = \sum q_{it} \; f_t \quad (3)$$

Where

q_{it} quality of component i

2.2.2 Optimization of the Blending Process Objective Function Equation

The objective function is to minimize the production cost of gasoline blend. Similar procedures to that in Vahedi (2002) were adopted. The component prices of gasoline used in this work are as shown in Table 1.

Table 1: Components Prices

COMPONENT	PRICE $/M^3$	TANKS
SRG	140	TK1
SRN	168	TK2
Reformate	135	TK3
FCCG	125	TK4
Dimate	100	TK5
AKYLATE	130	TK6

Therefore the objective function is given as

$$P = \sum CP_1 f_1 + CP_2 f_2 + CP_3 f_3 + CP_4 f_4 + CP_5 f_5 + CP_6 f_6$$

Where;
CP: Cost of production of gasoline RON.
f_i: Volume of RON.
CP_1 and f_1: Cost price and Volume of SRG
CP_2 and f_2: Cost price and Volume of SRN
CP_3 and f_3:Cost price and Volume of Ref
CP_4 and f_4:Cost price and Volume of FCCG
CP_5 and f_5: Cost price and Volume of Dimate
CP_6 and f_6: Cost price and Volume of Alkylate.

$$f_1+f_2+f_3+f_4+f_5+f_6 = f_t \quad (5)$$

f_t: total RON ‘volume

$$CP_1+CP_2+CP_3+CP_4+CP_5+CP_6 = CP$$

CP_i: component price

2.2.3 Constraints equations (Quality specification)

The quality specification of the product is given by upper and lower bounds:

$RON^L_i \leq RON_t \leq RON^U_i$

It is also assumed that there is upper and lower specification of the volume of a given blend component used in the final gasoline product. That is:

$$f_i^L \leq f_t \leq f_i^u \quad 6$$

The above formulated optimization problem is solved using MATLAB V7.5 compiler.

3.0 RESULTS AND DISCUSSION

The current cost of production at the refinery and output/results of the solved MATLAB program are as shown in the Table 2 to Table 5 below.

Table 2a: Refinery data for RON 89

PROD.RATE bbl/day	SRG	SRN	REF	FCCG	DIM	ALKY	Current COST $/m³
	RATE	RATE	RATE	RATE	RATE	RATE	
20000	1600	2200	3600	4400	4200	4000	129.06
15000	1200	1650	2700	3300	3150	3000	129.06
25000	2000	2756	4500	5500	5250	5000	129.06
26000	780	780	2600	5200	6500	10140	129.06
27000	2160	2970	4860	5940	5670	5400	129.06
18000	1440	1980	3240	3960	3780	3600	129.06
23000	1840	2530	4140	5060	4830	4600	129.06

Table 2b: Targeting minimization of RON 89 based on the model

PROD.RATE bbl/day	SRG	SRN	REF	FCCG	DIM	ALKY	OPT COST $/m³
	RATE	RATE	RATE	RATE	RATE	RATE	
20000	1400	1400	3000	5000	5600	3200	122.31
15000	1050	1050	2250	3750	4200	2400	122.31
25000	1750	1750	3500	6250	7000	4000	120.31
26000	780	520	2600	6760	10140	5200	122.31
27000	1890	1890	4050	6750	7560	4320	122.31
18000	1260	1260	2700	4500	5040	2880	122.31
23000	1610	1610	3450	5750	6440	3680	122.31

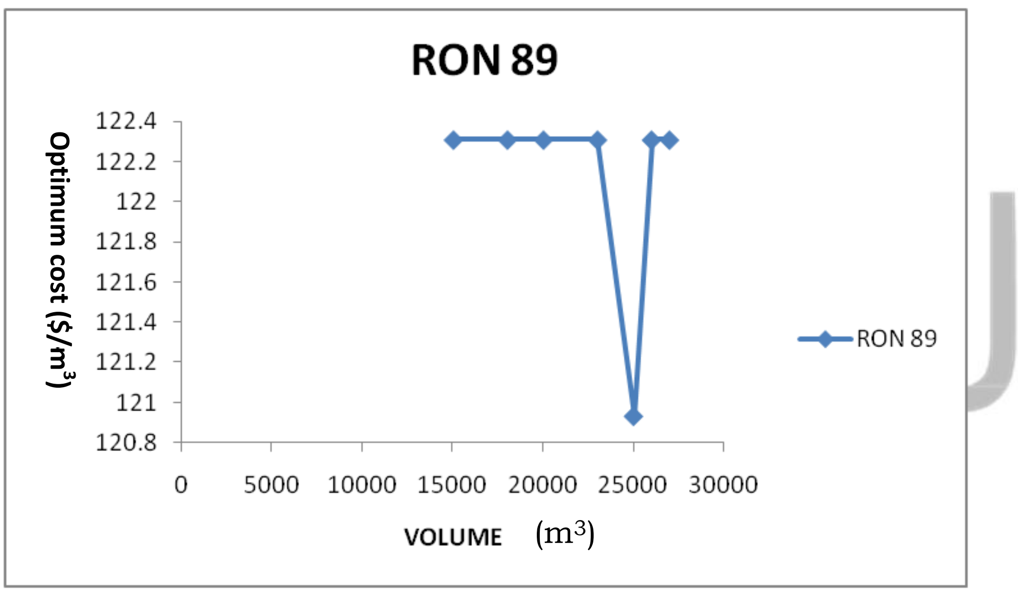

Fig. 1: PLOT OF OPTIMIZED COST ($/bbl) AGAINST VOLUME (m³)

Fig. 1 is a representation of the lab optimum cost of RON 89 versus the volume. It was observed that the optimum cost was maintained at $122.31/m^3$ but at a volume of 25000m³ the optimum cost reduced to $120.31/m^3$.

FOR RON 91

Table 3a: Refinery data for RON 91

PRODUCTION RATE bbl/day	**SRG**	**SRN**	**REF**	**FCCG**	**DIM**	**ALKY**	**CurrentC OST$/m3**
	RATE	RATE	RATE	RATE	RATE	RATE	
20000	1200	1600	3000	5200	5000	4000	126.04
15000	900	1200	2250	3900	3750	3000	126.04
25000	1500	2000	3750	6500	6250	5000	126.04
26000	1560	2080	3900	6760	6500	5200	126.04
27000	1620	2160	4050	7020	6750	5400	126.04
18000	1080	1440	2700	4680	4500	3600	126.04
23000	1380	1840	3450	5980	5750	4600	126.04

Table 3b: Targeting minimization of RON 91 based on the model

PROD.RATE bbl/day	SRG	SRN	REF	FCCG	DIM	ALKY	OPT COST $/m3
	RATE	RATE	RATE	RATE	RATE	RATE	
20000	1800	1000	2600	5400	5200	4000	124.69
15000	1350	750	1950	4050	3900	3000	124.69
25000	2250	1250	3250	6750	6500	5000	124.69
26000	2340	1300	3380	7020	6760	5200	124.69
27000	2430	1350	3510	7290	7020	5400	124.69
18000	1620	900	2340	4860	4680	3600	124.69
23000	2070	1150	2990	6210	5980	4600	124.69

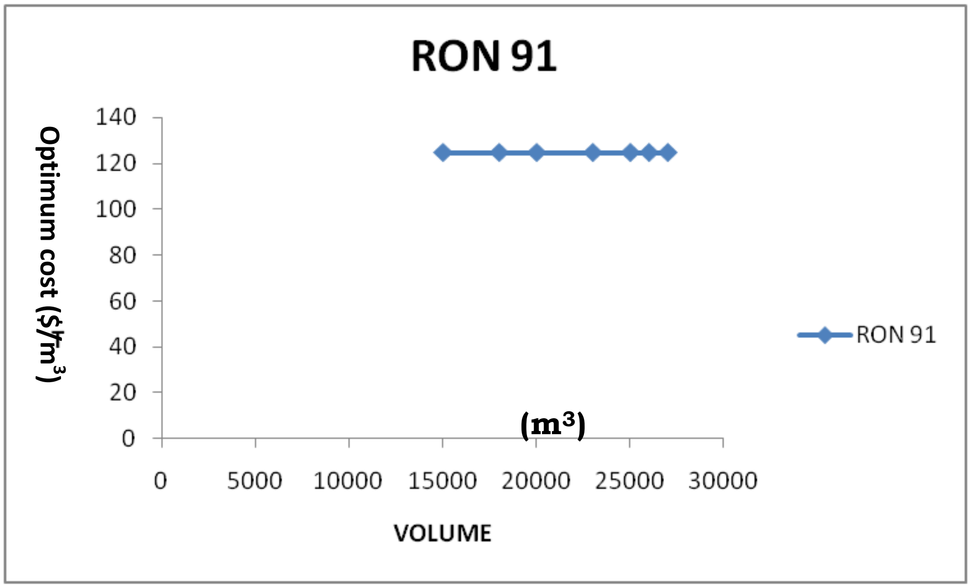

Fig.2: PLOT OF OPTIMIZED COST ($/bbl) AGAINST VOLUME ($m^3$)

Fig. 2 is a representation of the lab optimum cost of RON 91 against the volume. It was observed that at $124.69 the optimum cost was stabilized.

FOR RON 94

Table 4a: Refinery data for RON 94

PRODUCTION RATE bbl/day	SRG	SRN	REF	FCCG	DIM	ALKY	Current COST$/$m^3$
	RATE	RATE	RATE	RATE	RATE	RATE	
20000s	600	600	2000	4000	5000	7800	123.74
15000	450	450	1500	3000	3750	5850	123.74
25000	750	750	2500	5000	6250	9750	123.74
26000	2080	2860	4680	5720	5460	5200	123.74
27000	810	810	2700	5400	6750	10530	123.74
18000	540	540	1800	3600	4500	7020	123.74
23000	690	690	2300	4600	5750	8970	123.74

Table 4b: Targeting minimization of RON 94 based on model

PROD.RATE bbl/day	SRG	SRN	REF	FCCG	DIM	ALKY	OPT COST $/m³
	RATE	RATE	RATE	RATE	RATE	RATE	
20000	600	400	2000	5200	7800	4000	122.3
15000	450	300	2500	3900	5850	3000	122.3
25000	750	500	2500	6500	9750	5000	122.3
26000	1820	1820	3900	6500	7280	4160	122.3
27000	810	540	2700	7020	10530	5400	122.3
18000	540	360	1800	4680	7000	3600	122.3
23000	690	460	2300	5980	8970	4600	122.3

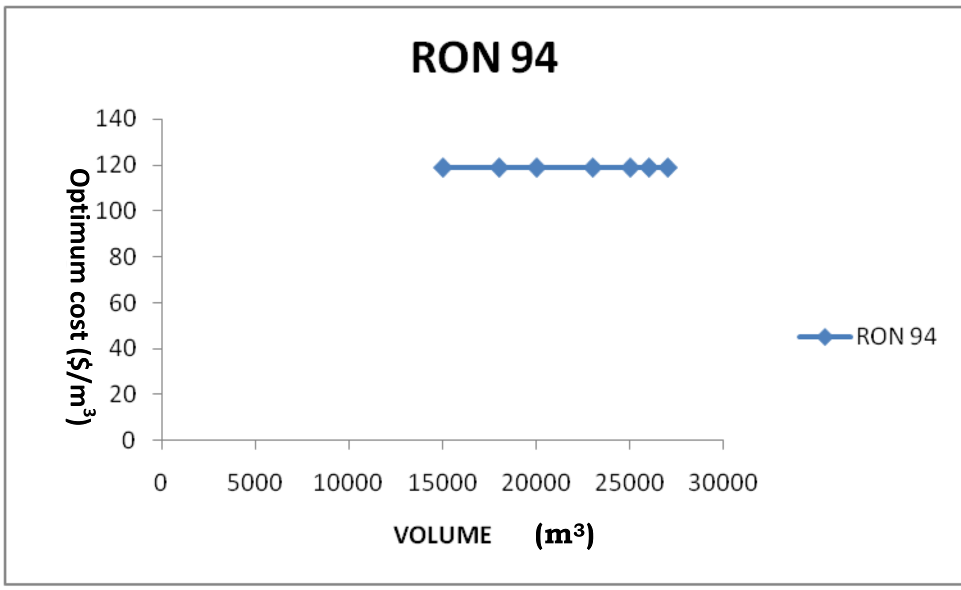

Fig.3: PLOT OF OPTIMIZED COST ($/bbl) AGAINST VOLUME (m³)

Fig. 3 is a representation of the lab optimum cost of RON 94 versus the volume. It was observed that at $122.30 the optimum cost was maintained.

Table 5: Variation between current cost and the minimized cost

RON	COST OF CURRENT PRODUCTION ($/m^3)	COST OF OPTIMIZED PRODUCTION ($/m^3)	VARIATION IN PRODUCTION ($/m^3)
89	129.06	122.31	6.75
91	126.04	124.69	1.35
94	123.74	122.30	1.44

4.0 CONCLUSION

The objective of this research was to come out with a model for optimization of gasoline blending process which will reduce the cost of production price while maintaining the quality and quantity of the constraints. Six (6) different gasoline types were blended to produce a gasoline of RON 89, 91 and 94. The blending model and the optimization model were developed and MATLAB code was written to solve the equation using linear programming solution method. The lowest octane number is the SRG (tank1) while the highest octane number is the Alkylate (tank6). The model was used to prepare a blending of RON 89, 91 and 94 which after optimization yielded a reduction in cost of production with maximum refinery benefits when compared to the current refinery cost of production as well as the quality constraint. The gasoline produced satisfied the African Refining Association (ARA) specification.

5.0 RECOMMENDATION

- Further development of the optimization model should include other properties of gasoline like the Reid Vapor Pressure (RVP), Motor Octane Number (MON) and Specific Gravity (SPG) etc.

REFERENCES

African Refiners Association, (2010). http//www.afrra.org Accessed on the 13th February. 2014.

Afri Specification, (2010). African Refiners Association UNEP Meeting Rabat. http//www.afrra.unep.org Accessed on the 18th February 2014

Celik, M. B. (2008) Experimental determination of suitable ethanol-gasoline blend rate at high compression ratio for gasoline engine.

Diab M.G, Mustafa H.M, I .H. M.Elamin H.M, and Gasmelseed G.A. (2014). “Optimization of Motor Gasoline Production”. Journal of Applied and Industrial Sciences, 2 (3): 100-105

Moore W., Foster, M and Hoyer, K (2011) "Engine Efficiency Improvements Enabled by Ethanol Fuel Blends in GDi VVA Flex Fuel Engine". SAE Technical Paper.

Port Harcourt Refinery Company (2008). “Blending and Tank Farm Operations”.*Operational Manual for MOP.*

Port Harcourt Refinery Company (2010). “Distillation Process”.*Operational Manual for CDU*, Port Harcourt.

Rusin, M.H., Chung, H.S., and Marshall, J.F (1981). “A Transformation Method for Calculating the Research and Motor

Octane Numbers of Gasoline Blends", Ind.

Vahid Vahedi (2002), Data Based Dynamic Optimization "Thesis on Modeling for

Eng. Chem. Fundam., 20(3), pp195-204.

Refinery Optimization" Chemical Engineering. Bookpartner, Nørhaven Digital, Copenhagen, Denmark pp1-10.