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Upgrading the Commercial Gasoline A80 by Using Ethanol and Refinery Products

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Abstract— Gasoline A80 has high percentages of benzene and aromatic content which are carcinogenic materials. Upgrading gasoline A80 has a positive effect on our environment because it produces an environmental gasoline which has less percentages of benzene and aromatic content in order to serve our country. Furthermore, upgrading gasoline A80 is the main target to produce an environmental gasoline by using blends of gasoline A80 and Refinery products from upgrading and conversion units and thus the Environmental gasoline is produced to approach to the standard European regulations of A92. In other words, three samples of reformate, isomerate, Coker naphtha and hydrocracked naphtha are blended separately with gasoline A80. In addition, the three samples of oxygenated compounds (Ethanol) and gasoline A80 are blended to produce the environmental gasoline. The physico-chemical characteristics have been studied such as density, Reid Vapor Pressure, ASTM distillation, Research Octane Number, Motor Octane Number, posted Octane Number, PIONA and benzene content to select the optimum sample of an environmental gasoline. Moreover, the composition of the optimum sample, a new blend of environmental gasoline, is E7.5 C3.75 H14 R27.5 I2.5 G44.75 and it is chosen according to Standard European regulations. This sample contains mainly 39.5 vol. % aromatic content, 28.9 vol. % isoparaffins and 1.1 vol. % benzene content. Therefore, this optimum sample in the overall case exactly meets the conditions of Euro-3 and approach to Euro-6 regulations. Finally, upgrading for gasoline A80 is achieved to obtain gasoline A92 as an environmental gasoline (It is the best solution in the short run).

Index Terms— Euro-6, Gasoline A 80, ASTM distillation, RVP, RON, MON, PIONA, benzene content.

1 Introduction

The Gasoline is a complex mixture of hydrocarbons obtained from crude oil distillation and processing, as well as the other organic chemicals derived from other energy sources. Modern gasoline is a heavily processed product that can also contain various synthetic components, added to improve its performance and meet the demands of today's advanced engine technology [1]. Components are blended to promote high antiknock quality, ease of starting، quick warm up, low tendency to vapor lock, and low engine deposits. The components used in blending motor gasoline can be limited to light straight-run (LSR) gasoline or isomerate, catalytic reformate, catalytically cracked gasoline, Hydrocracked gasoline, polymer gasoline, alkylate, n-butane, and One of the most important additives to improve fuel performance is oxygenates (oxygen containing organic compounds) such additives as MTBE (methyl tertiary butyl ether), ETBE (ethyl tertiary butyl ether), TAME (tertiary amyl methyl ether) and ethanol [2]. Presently, ethanol is prospective material for use in automobiles as an alternative to petroleum based fuels. The main reason for advocating ethanol is that it can be manufactured from natural products or waste materials, compared with gasoline, which is produced from non-renewable natural resources. In addition, ethanol shows good anti-knock characteristics. However, economic reasons still limit its usage on a large scale. At the present time and instead of pure ethanol, a blend of ethanol and gasoline is a more attractive fuel with good anti-knock characteristics [3]. The addition of solvents changes the original composition of the fuel, affecting in physicochemical properties in different ways [4]. Distillation curves, vapor pressure and octane rating are properties closely related to the fuel composition and the characteristics of its components [5, 6, 7]. Furthermore, ethanol is used as gasoline additives to reduce pollutants from vehicle exhaust gases. Proponents of these oxygenates claim several advantages: they are octane enhancers [8], they have significant anti-knock properties important for unleaded fuels, they can be produced from renewable agricultural raw materials instead of fossil sources, and they reduce carbon monoxide emission from vehicle exhaust. Moreover, they reduce the emission of unburned hydrocarbons and minimize the emission of volatile organic compounds. Many trials are made to enhance the properties of gasoline in order to produce an environmental gasoline such as: EL-Bassiouny et al. [9] investigated the Maximize of the Production of Environmental, Clean and High Octane Number Gasoline-Ethanol Blends by using Refinery Products. Moreover, Straight run naphtha, isomerate, reformate, Coker naphtha and hydrocracked naphtha which produced from crude distillation unit, isomerization process, catalytic reforming and conversion processes respectively are blended with an oxygenated compound (ethanol) to produce environmental gasolines A98 and A95 respectively which satisfy all specification of Euro-6 regulations. The new blends are friendly environmental and contains the less amount of benzene content.It is the best solution for the long run. Hakan Bayraktar [10] studied the effects of ethanol addition to gasoline

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on an SI engine performance and exhaust emissions experimentally and theoretically. Experimental applications have been carried out with the blends containing 1.5, 3, 4.5, 6, 7.5, 9, 10.5 and 12 vol. % ethanol. Experimental results have shown that among the various blends, the blend of 7.5 vol. % ethanol was the most suitable one from the engine performance and CO emissions. Khamis and Palichev [11] investigated the production of stock gasoline with ultra-low sulphur content up to 10 ppm (Euro-5 Standard) by blending of different gasoline streams produced in the Lukoil Nentochim Bourgas (LNHB) refinery units as well as on the study on the efficiency of ferrocene antiknock additives. Some recipes for the production of stock gasolines A92, A95, and A98 commercial grades on the basis of component streams produced in LNHB refinery units and satisfying all specifications of the European regulations were elaborated. Thus, the gasoline blending provides a great potential benefit to the refinery in view of minimizing operating costs and product quality improvement. Soheil et al. [12] studied the effect of oxygenate additives into gasoline for the improvement of physico-chemical properties of blends. Methyl Tertiary Butyl Ether (MTBE), Methanol, Tertiary Butyl Alcohol (TBA), and Tertiary Amyl Alcohol (TAA) blend into unleaded gasoline with various blended rates of 2.5, 5, 7.5, 10, 15, and 20 vol. % respectively. Physico-chemical properties of blends are analyzed by the standard American Society of Testing and Materials (ASTM) methods. Methanol, TBA, and TAA increase the density of the mixtures, but MTBE decreases density. The addition of oxygenates lead to a distortion of the base gasoline's distillation curves. The Reid vapor pressure (RVP) of gasoline is found to increase with the addition of the oxygenated compounds. All oxygenates improve both motor and research octane numbers. Christensen et al.[13] Studied the chemical and physical properties (RVP, vapor lock protection, ASTM distillation, density, octane rating, viscosity and potential for extraction into water) for various alcohol–gasoline blends of up to 3.7% w/w of oxygen and has compared them with the requirements of the ASTM D4814 specification to determine their utility as gasoline extenders.

The purpose of this study is to investigate the physico-chemical characteristics of Gasoline A80 blended separately with Coker Naphtha, Hydrocracked Naphtha, Reformate, Isomerate and Ethanol and thus Study the Physico-chemical Characteristics of the optimum sample to upgrade gasoline A80 to reach gasoline A92. Production of an environmental gasoline is the main target of this research.

2 MATERIALS AND METHODS

To carry out this research some fuels and experimental facilities that comply with European standards were used.

2.1 Fuel blends

The aim of our research, i.e. Upgrading commercial gasolines A80 to an environmental gasoline approach to A92 according to Euro-6 regulations is accomplished by using the following refinery fractions in Egypt:

1. Reformate.
2. Isomerate.
3. Hydrocracked Naphtha.
4. Coker Naphtha
5. Ethanol.
6. Gasoline A80

By blending of the above-pointed products in a system for mixing of the semi-finished products, gasoline blends are obtained and thus tested according to Standard European Regulations (Euro-6).

2.2 Fuel Properties Determination

Fuel properties of tested blends are determined in accordance with American Standard for Testing Materials (ASTM) procedures for petroleum products. Comprehensive analyses are carried out to document fuel properties of the tested blends. Each fuel sample is evaluated to determine the density, RVP, ASTM distillation, RON, MON, PON, PIONA and benzene content. Figs 1-6 lists various apparatus employed in the determination of these fuel properties. The density of each tested sample is measured by density meter apparatus (ASTM 4052) [14]. The ASTM distillation curve is determined by ASTM distillation device in accordance with ASTM D86 [15]. The Reid vapor pressure is determined by Reid vapor pressure device in accordance with ASTM D 5191[16]. The blends Octane rating is determined by a Cooperative Fuels Research (CFR) Engine and octane meter apparatus for research octane number (ASTM D2699)[17] and motor octane number (ASTM D 2700)[18]. The Hydrocarbon type content is obtained by Gas chromatography in accordance with ASTM D 6839 [19].

3 RESULTS AND DISCUSSION

In this section the main results obtained from the tests (RVP، RON, MON, PON, distillation curve, density and composition) are shown and discussed. In addition, table 1 shows The Composition of Gasoline A80-blend Samples.

3.1 Physico-chemical Characteristics of Gasoline A80-Ethanol Blends.

Different percentages of ethanol are added to gasoline A80 and observe the effect of each percentage on it .Some measurements are made such as Reid Vapor Pressure, density, research octane number, motor octane number, ASTM distillation, PIONA, and benzene content according to ASTM methods. E2.5, E5 and E7.5 are added to gasoline A80 to produce the environmental gasoline. Table 2 shows Physico-chemical characteristics of gasoline A80-ethanol blends. It illustrates density, RVP, RON, MON, PON, ASTM distillation and PIONA for them. The optimum selected sample contains the minimum percent of aromatics (38.6 vol. %). Moreover, the benzene content in this sample is (0.9 vol. %). At the same time, volumes at 100 ^oC and 150 ^oC are 53 and 90.3 vol. % respectively. The FBP and distillation residue is 198 ^oC and 1.3 vol. % respectively.

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3.1.1 Octane Number Measurement

Research octane number, Motor octane number, and Posted octane number (R+M)/2 are measured when ethanol is added to gasoline A80. Figure 7 shows relationship between octane numbers and gasoline A80-ethanol blends. The octane numbers (RON, MON and PON) is increased continuously and linearly with increasing percentages of ethanol. The optimum sample is E7.5 which has RON, MON and PON is 101, 95.9 and 98.45 respectively.

3.3.2 Density and Reid Vapor Pressure

Figure 8 shows the density and Reid vapor pressure curves versus ethanol percent in gasoline A80. For small concentration of ethanol, the density and Reid vapor pressure values increase with increasing ethanol percentage and for high percentages of ethanol, the density values increase and Reid vapor pressure values decrease with increasing ethanol percentage. The density and Reid vapor pressure of optimum sample are 744.9 kg/m^3 and 56 kPa respectively.

3.3.3 ASTM Distillation

As mentioned previously (part1), the presence of high alcohol percentages in gasoline depresses the distillation curve of fuel which can cause problem with cold starting and vapor lock. Figure 9 demonstrates ASTM Distillation curve for gasoline A80-ethanol blend samples. The optimum selected sample is E 7.5 .The Volumes of it at 100 ^{o}C and 150 ^{o}C are 53and 90.3 vol. % respectively, the FBP of it is 198 ^{o}C and its distillation residue is 1.3 vol. %. These results approach to the standard European regulations (Euro-6).

3.3.4 Gas Chromatography (PIONA)

Figure 10 shows the composition of gasoline A80-ethanol blend samples by gas chromatography. It illustrates the percentages of parrafins, iso-parrafins, aromatics, naphthenes and olefins. For more explanation, the aromatic percentages in E2.5, E5 and E7.5 are 41, 39.6 and 38.6 vol. % respectively. Finally, the optimum sample is selected according to less one in the aromatic content (E7.5).The percentage of benzene content is 0.9 vol. % and thus the percentage of benzene is satisfactory according to the European regulations of the environmental gasoline which has less amount of emissions.

3.2 Physico-chemical Characteristics of Gasoline A80-Coker Naphtha Blend Samples

Different percentages of Coker naphtha are added to gasoline A80 and observe the effect of each percent on gasoline A80 .Some measurements are made such as Reid Vapor Pressure, density, research octane number, motor octane number, ASTM distillation, PIONA, and benzene content according to ASTM methods. The percentage of Coker naphtha are 1.25, 2.5, and 3.75 vol. % respectively. Table 3 shows Physico-chemical characteristics of gasoline A80-coker naphtha blends. It illustrates density, RVP, RON, MON, PON, ASTM distillation and PIONA for them. The optimum selected sample contains the minimum percent of aromatics (41 vol. %). Moreover, the benzene content in this sample is (1 vol. %). At the same time, volumes at 100 ^{o}C and 150 ^{o}C are 49.8 and 90.3 vol. % respectively. The FBP and distillation residue is 197.5 ^{o}C and 1.1 vol. % respectively.

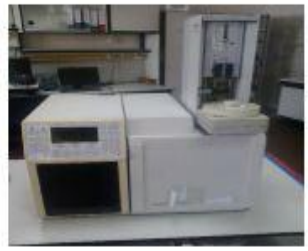

Fig.1 Gas Chromatography Apparatus.

Fig.4 Cooperative Fuels Research (CFR) Engine.

Fig.2 Density Meter Apparatus.

Fig.5 Reid Vapor Pressure Apparatus.

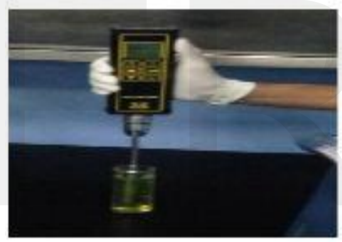

Fig.3 Reid Vapor Pressure Apparatus.

Fig.6 Reid Vapor Pressure Apparatus.

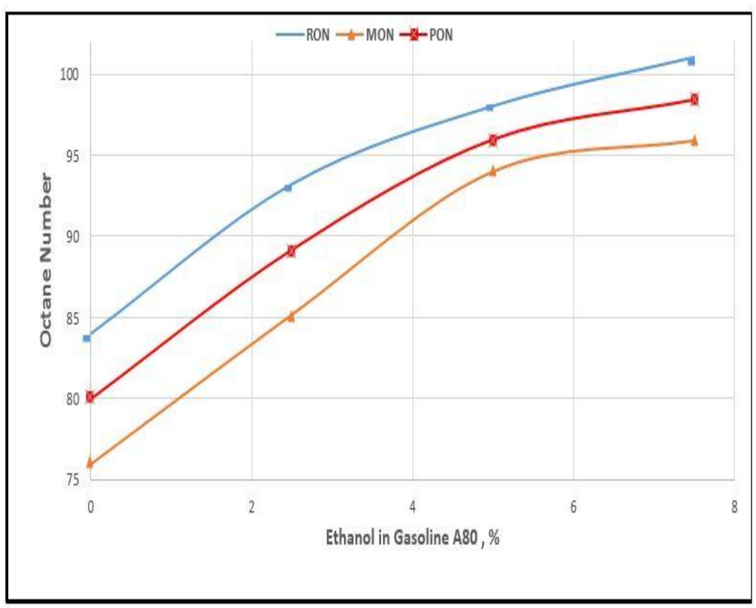

Fig. 7 Relationship between Octane Numbers and Gasoline A80 -Ethanol blends.

Table 1 The Composition of Gasoline A80-blend Samples.

Gasoline A80-Ethanol blends			Gasoline A80-Coker Naphtha blends			Gasoline A80-Hydrocracked Naphtha blends			Gasoline A80-Reformate blends			Gasoline 80-Isomerate blends		
Sample 28	Sample 29	Sample 30	Sample 31	Sample 32	Sample 33	Sample 34	Sample 35	Sample 36	Sample 37	Sample 38	Sample 39	Sample 40	Sample 41	Sample 42
2.5 %	5 %	7.5 %	1.25 %	2.5 %	3.75 %	8 %	11 %	14 %	22.5 %	25 %	27.5 %	2.5 %	5 %	7.5 %

Table 2 Physico-chemical Characteristics of Gasoline A80-Ethanol Blends.

Test	Method	Units	Sample No.		
			Sample 28 $E_{2.5}G_{97.5}$	Sample 29 E_5G_{95}	Sample 30 $E_{7.5}G_{92.5}$
Density at 15 °C	ASTM D4052	Kg/m³	741.4	743.3	744.9
Reid Vapor Pressure	ASTM D5191	kPa	53	55	**56**
RON	ASTM D2699		93.2	98	101
MON	ASTM D2700		85.2	94	95.9
PON	(R+M)/2		89.2	96	98.45
Distillation at 100 °C	ASTM D86	Vol. %	51.6	52	53
at 150 °C		Vol. %	89	90.1	90.3
at FBP		°C	202	199.4	198
Distillation Residue		Vol.%	1.6	1.4	1.3
composition	ASTM D6729				
Paraffins		Vol. %	17.2	16.6	16.1
Iso- Paraffins		Vol. %	25.4	25.1	24.7
Olefins		Vol. %	1.8	1.8	1.7
Naphthenes		Vol. %	12.2	11.9	11.5
Aromatics		Vol. %	41	39.6	**38.6**
oxygenates		Vol. %	2.4	5.0	7.5
Benzene		Vol. %	0.9	0.9	**0.9**
Toluene		Vol. %	7.2	7.1	7.0
Ethyl benzene		Vol. %	1.6	1.6	1.5
m-Xylene		Vol. %	4.0	4.0	3.9
p-Xylene		Vol. %	1.7	1.7	1.6
o-Xylene		Vol. %	2.2	2.2	2.2

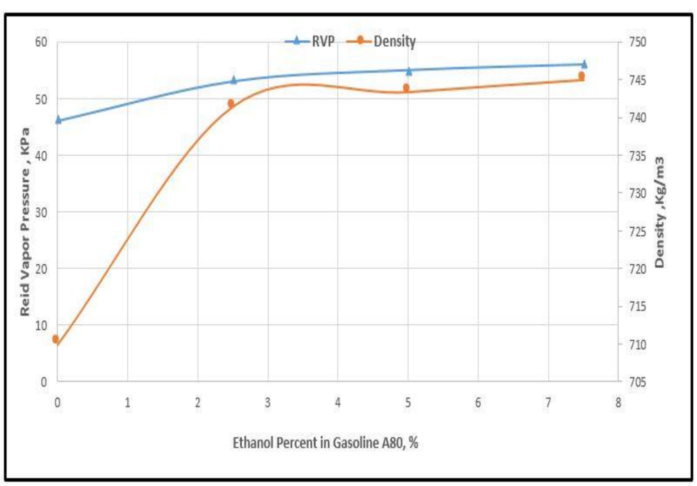

Fig.8 Density and Reid Vapor Pressure Curves versus Ethanol Percent in Gasoline A80 Blend.

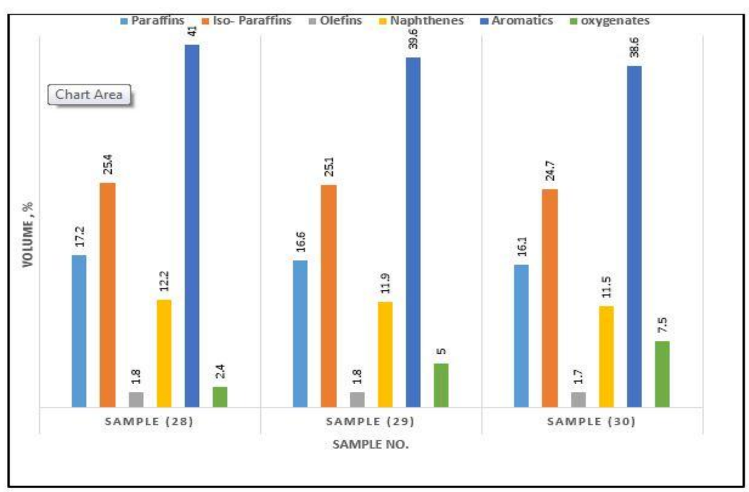

Fig. 10 The Composition of Gasoline A80- ethanol Blend Sample by Gas Chromatography.

3.2.1 Octane Number Measurement

Research octane number, Motor octane number, and Posted octane number are measured when Coker naphtha is added to gasoline A80. Figure 11 shows relationship between octane numbers and gasoline A80-Coker naphtha blends. The octane numbers (RON, MON and PON) increase continuously and linearly with increasing percentages of Coker naphtha. Finally, the optimum sample is C 3.75 which has RON, MON and PON is 87, 78.4 and 82.7 respectively.

4.2.2 Density and Reid Vapor Pressure

Figure 12 demonstrates the density and Reid vapor pressure curves versus Coker naphtha percent in gasoline A80.it shows that the density values increase and Reid vapor pressure values decrease with increasing Coker naphtha percentage. The density and Reid vapor pressure value of the optimum sample are 745.9 kg/m^3 and 41.5 kPa respectively.

3.2.3 ASTM Distillation

Figure 13 demonstrates ASTM distillation curves for gasoline A80 –Coker naphtha blend samples. The optimum selected sample is C 3.75 and the Volumes of it at 100 ^oC and 150 ^oC are 48.8 and 90.3 vol. % respectively. In addition, the FBP of it is 197.5^oC and its distillation residue is 1.1 vol. %. These results approach to the standard European regulations (Euro-6).

3.2.4 Gas Chromatography (PIONA)

Figure 14 shows the composition of gasoline A80-Coker naphtha blend samples by Gas Chromatography. It illustrates the percentages of parrafins, iso-parrafins, aromatics, naphthenes and olefins. Clearly, the aromatic percentages in C1.25, C2.5 and C3.75 are 41.4, 41.3 and 41 vol. % respectively. Finally, the optimum sample is selected according to less one in the aromatic content (C 3.75). The percentage of benzene content is 1 vol. % and thus the percentage of benzene is satisfactory according to the European regulations of the environmental gasoline which has less amount of emissions.

3.3 Physico-chemical Characteristics of Gasoline A80-Hydrocracked Naphtha Blend Samples

Different percentages of Hydrocracked naphtha are added to gasoline A80 and observe the effect of each percent on gasoline A80 .Some measurements are made such as Reid Vapor Pressure, density, research octane number, motor octane number, ASTM distillation, PIONA, and benzene content according to ASTM methods. The percentage of Hydrocracked naphtha are 8, 11, and 14 vol. % respectively. Table 4 shows physico-chemical characteristics of gasoline A80-Hydrocracked naphtha blends. It illustrates density, RVP, RON, MON, PON, ASTM distillation and PIONA for them. The optimum selected sample contains the minimum percent of aromatics (40.4 vol. %). Moreover, the benzene content in this sample is (1 vol. %). At the same time, the volume percentages at 100 oC and 150 ^oC are 50.3 and 90.6 vol. % respectively. Finally, the FBP and distillation residue is 199.0 ^oC and 1.4 vol. % respectively.

3.3.1 Octane Number Measurement

Research octane number, Motor octane number, and Posted octane number are measured when hydrocracked Naphtha is added to gasoline A80. Figure 15 shows relationship between octane numbers and gasoline A80-Hydrocracked naphtha blends. The octane numbers (RON, MON and PON) decrease suddenly and continuously with increasing percentages of Hydrocracked naphtha. The Research octane number for H8, H11 and H14 is 85.8, 85.1 and 85 respectively. Finally, the optimum sample is H14 which has RON, MON and PON is 85, 78.2 and 81.6 respectively.

3.3.2 Density and Reid Vapor Pressure

Figure 16 demonstrates the density and Reid vapor pressure curves versus Hydrocracked naphtha percent in gasoline A80. It shows that the density values increase and Reid vapor pressure values decrease with increasing hydrocracked naphtha percentage .The density and Reid vapor pressure of the optimum sample are 740.9 kg/m^3 and 42 kPa respectively.

3.3.3 ASTM Distillation

Figure 17 demonstrates ASTM Distillation curves for gasoline A80 - Hydrocracked naphtha blend samples. The optimum selected sample is H 14 because of the least aromatic content .The Volumes of it at 100 ^oC and 150 ^oC are 50.3 and 90.6 vol. % respectively, the FBP of it is 199^oC and its distillation residue is 1.4 vol. %. These results approach to the standard European regulations (Euro-6).

3.3.4 Gas Chromatography (PIONA)

Figure 18 shows the composition of gasoline A80-Hydrocracked naphtha blend samples by Gas Chromatography. It illustrates the percentages of parrafins, iso-parrafins, aromatics, naphthenes and olefins. For more explanation, the aromatic percentages in H8, H11 and H14 are 41.1, 40.7 and 40.4 vol. % respectively. The percentage of benzene content is 1 vol. % and thus it is satisfactory according to the European regulations of the environmental gasoline which has less amount of emissions. Finally, the optimum sample is selected according to less one in the aromatic content (H14).

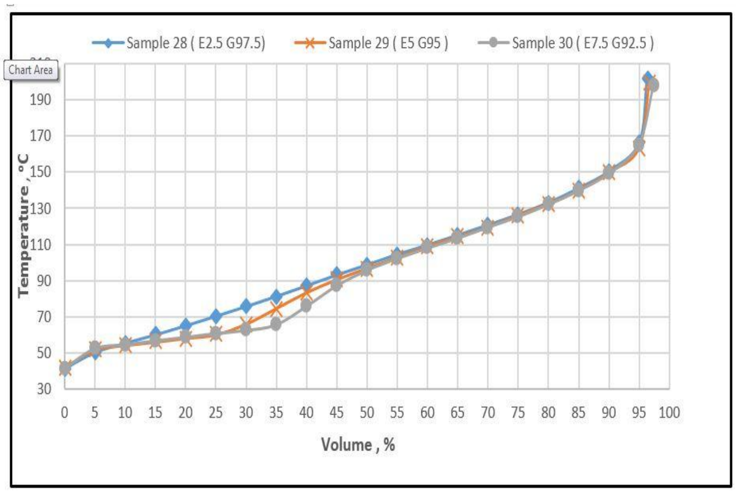

Fig. 9 ASTM Distillation Curve for Gasoline 80 -Ethanol Blend Samples.

Table 3 Physico-chemical Characteristics of Gasoline A80-Coker Naphtha Blend Samples.

Test	Method	Units	Sample No.		
			Sample 31	Sample 32	Sample 33
		composition	$C_{1.25}G_{98.75}$	$C_{2.5}G_{97.5}$	$C_{3.75}G_{96.25}$
Density at 15 °C	ASTM D4052	Kg/m^3	741.4	741.9	745.9
Reid Vapor Pressure	ASTM D5191	kPa	44	43	41.5
RON	ASTM D2699		86.1	86.4	87
MON	ASTM D2700		78.8	78	78.4
PON	(R+M)/2		82.45	82.2	82.7
Distillation at 100 °C	ASTM D86	Vol. %	50	49.6	49.8
at 150 °C		Vol. %	90.1	90.6	90.3
at FBP		°C	201.8	199.0	197.5
Distillation residue		Vol. %	1.3	1.5	1.1
composition	ASTM D6729				
Paraffins		Vol. %	17.8	17.9	18
Iso- Paraffins		Vol. %	26.4	26.3	26.2
Olefins		Vol. %	2	2.1	2.3
Naphthenes		Vol. %	12.5	12.5	12.5
Aromatics		Vol. %	41.4	41.3	41
oxygenates		Vol. %	0.0	0.0	0.0
Benzene		Vol. %	1.0	1.0	1.0
Toluene		Vol. %	7.5	7.4	7.4
Ethyl benzene		Vol. %	1.7	1.6	1.6
m-Xylene		Vol. %	4.2	4.1	4.1
p-Xylene		Vol. %	1.8	1.7	1.7
o-Xylene		Vol. %	2.4	2.3	2.3

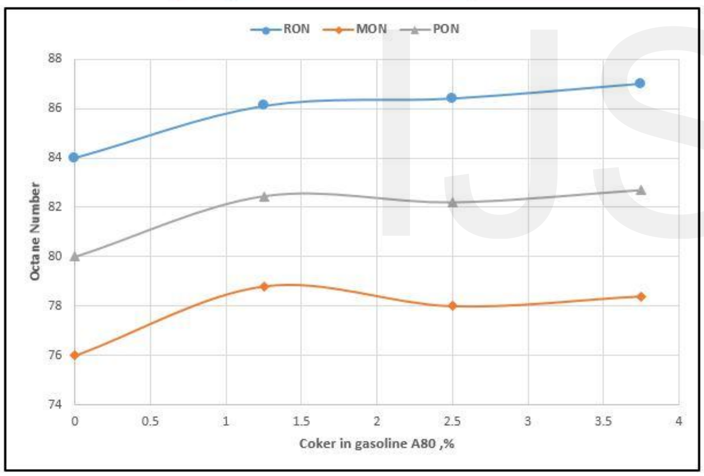

Fig. 11 Relationship between Octane Numbers and Gasoline A80-Coker Naphtha blends.

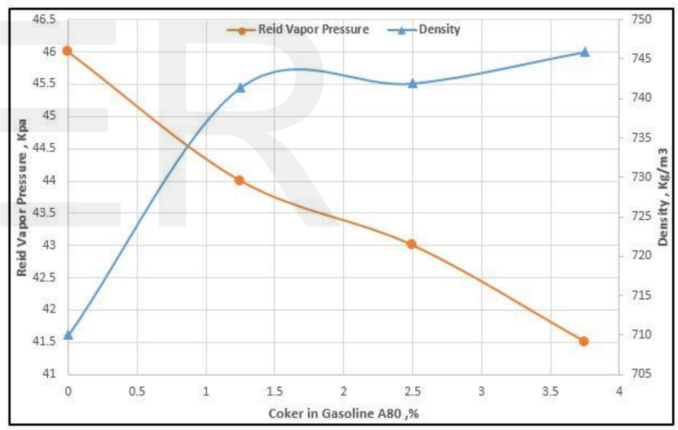

Fig. 12 Density and Reid Vapor Pressure Curves versus Coker Naphtha Percent in Gasoline A80 Blend.

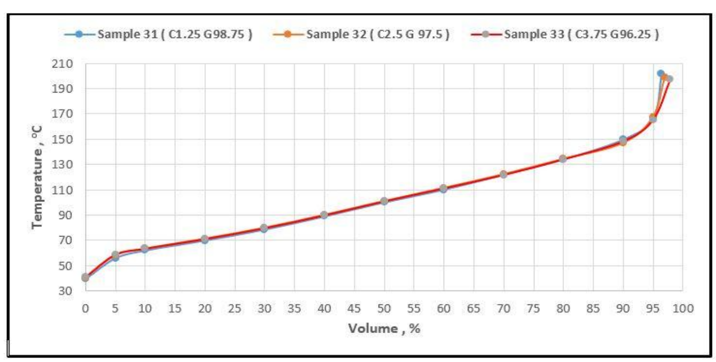

Fig. 13 ASTM Distillation Curves for Gasoline A80-Coker Naphtha Blend Samples.

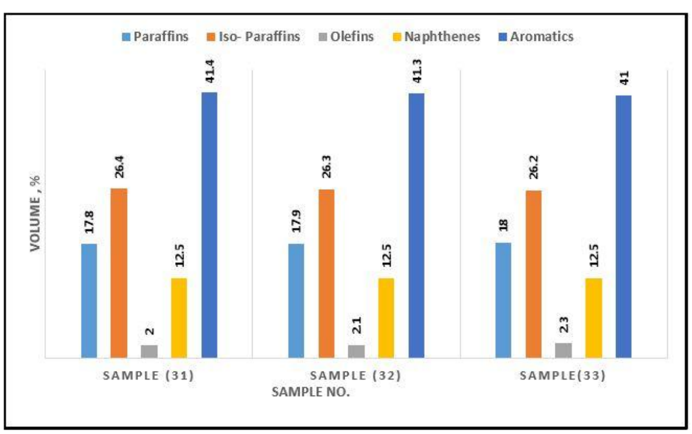

Fig. 14 the Composition of Gasoline A80- Coker Naphtha Blend Sample by Gas Chromatography.

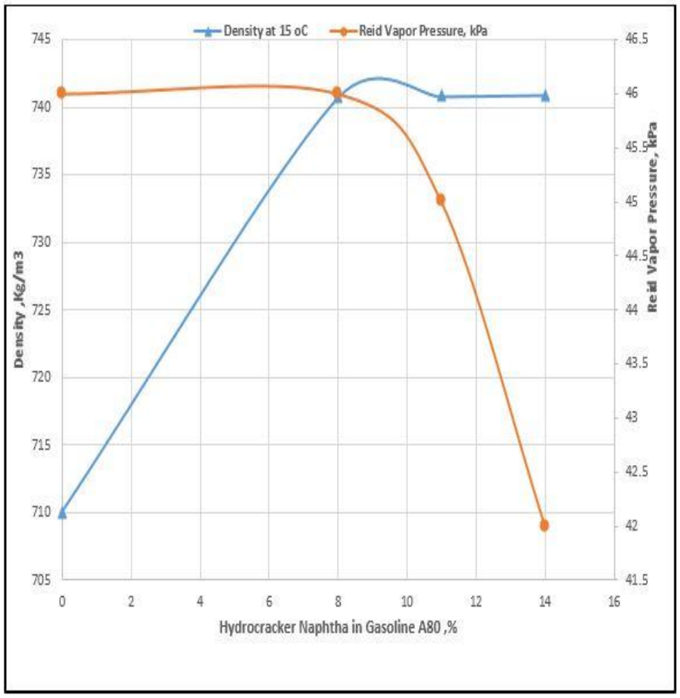

Fig. 16 Density and Reid Vapor Pressure Curves versus Hydrocracked Naphtha Percent in Gasoline A80 Blend.

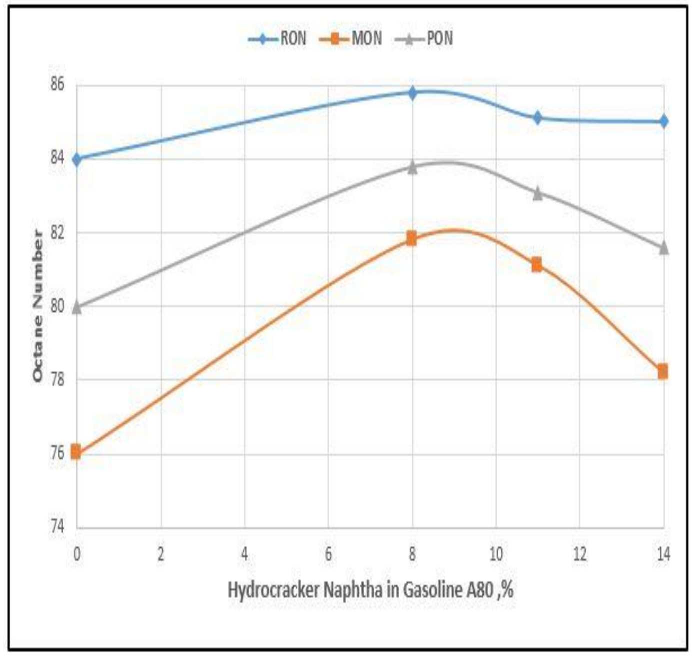

Fig. 15 Relation ship among octane numbers and gassoline A80- Hydrocracked Naphtha blends.

Table 4 Physico-chemical Characteristics of Gasoline A80-Hydrocracked Naphtha Blend Samples.

Test	Method	Units	Sample No.		
			Sample 34	Sample 35	Sample 36
composition			H_8G_{92}	$H_{11}G_{89}$	$H_{14}G_{86}$
Density at 15 °C	ASTM D4052	Kg/m^3	740.7	740.8	740.9
Reid Vapor Pressure	ASTM D5191	kPa	46	45	42
RON	ASTM D2699		85.8	85.1	85
MON	ASTM D2700		81.8	81.1	78.2
PON	(R+M)/2		83.8	83.1	81.6
Distillation at 100 °C	ASTM D86	Vol. %	50.1	50.9	50.3
at 150 °C		Vol. %	90.1	90.9	90.6
at FBP		°C	199.5	198.5	199.0
Distillation Residue		Vol. %	1.3	1.5	1.4
composition	ASTM D6729				
Paraffins		Vol. %	18.1	18.2	18.3
Iso- Paraffins		Vol. %	25.5	25.1	24.8
Olefins		Vol. %	1.7	1.7	1.6
Naphthenes		Vol. %	13.6	14.1	14.9
Aromatics		Vol. %	41.1	40.7	**40.4**
oxygenates		Vol. %	0.0	0.0	0.0
Benzene		Vol. %	1.0	1.0	**1.0**
Toluene		Vol. %	7.3	7.2	7.2
Ethyl benzene		Vol. %	1.6	1.6	1.6
m-Xylene		Vol. %	4.0	3.9	3.9
p-Xylene		Vol. %	1.7	1.6	1.6
o-Xylene		Vol. %	2.2	2.2	2.1

3.4 Physico-chemical Characteristics of Gasoline A80 - Reformate Blend Samples.

Different percentages of Reformate are added to gasoline A80 and observe the effect of each percent on gasoline A80. The percentages of reformate are 22.5, 25, and 27.5 vol. % respectively. Some measurements are made such as Reid Vapor Pressure, density, research octane number, motor octane number, ASTM distillation, PIONA, and benzene content according to ASTM methods. Table 5 shows physico-chemical characteristics of gasoline A80-reformate blends. It represents the values of density, RVP, RON, MON, PON, ASTM distillation and PIONA for them. After analyses, the optimum selected sample contains the minimum percent of aromatics (34.6 vol. %). Moreover, the benzene content in this sample is (1.4 vol. %). At the same time, volumes at 100 ^{o}C and 150 ^{o}C are 38.6 and 84.6 vol. % respectively. The FBP and distillation residue is 205 oC and 0.6 vol. % respectively.

3.4.1 Octane Number Measurement

Research octane number, Motor octane number, and Posted octane number are measured when reformate is added to gasoline A80. Figure 19 shows relationship between octane numbers and gasoline A80-reformate blends. The octane numbers (RON, MON and PON) increase continuously and linearly with increasing percentages of Reformate. The Research octane number for R22.5, R25 and R27.5 is 91.6, 92 and 92.2respectively.Finally, the optimum sample is H14 which has RON, MON and PON is 92.2, 83 and 87.6 respectively.

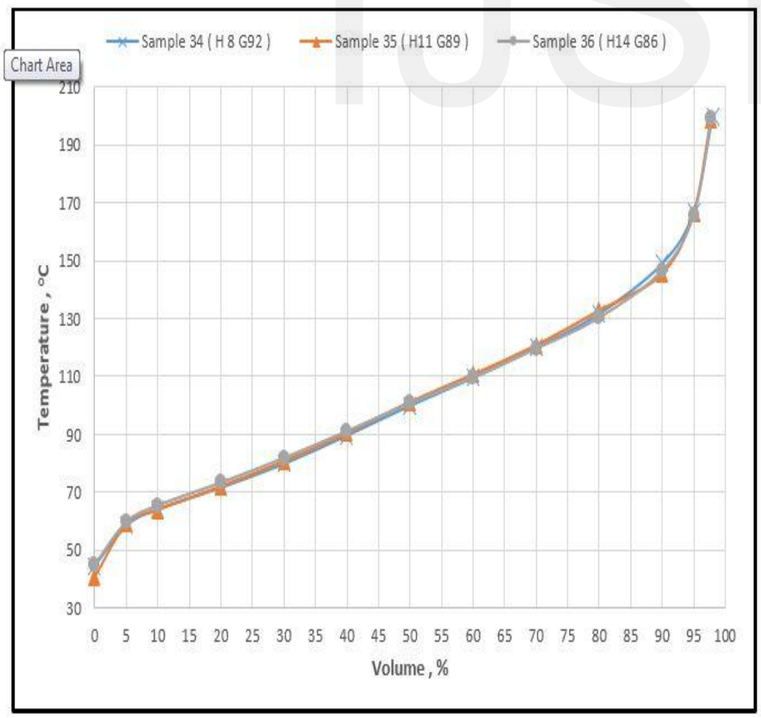

Fig. 17 ASTM Distillation Curves for Gasoline A80-Hydrocracked Naphtha Blend Samples.

3.4.2 Density and Reid Vapor Pressure

Figure 20 illustrates the density and Reid vapor pressure curves versus Reformate percent in gasoline A80. It shows that the density values increase and Reid vapor pressure values decrease with increasing reformate percentage. The density values of R22.5, R25 and R27.5 are 759.3, 762.0 and 765.8 Kg/m^3 and its Reid vapor pressure percentages are 39, 37 and 35 kPa. The density and Reid vapor pressure values of the optimum sample are 765.8 kg/m^3 and 35 kPa respectively.

3.4.3 ASTM Distillation

Figure 21 shows ASTM Distillation curves for gasoline A80-Reformate blend samples. The optimum selected sample is R 27.5 and volumes of it at 100 ^{o}C and 150 ^{o}C are 38.6 and 84.6 vol. % respectively. In addition, the FBP of it is 205.0^{o}C and its

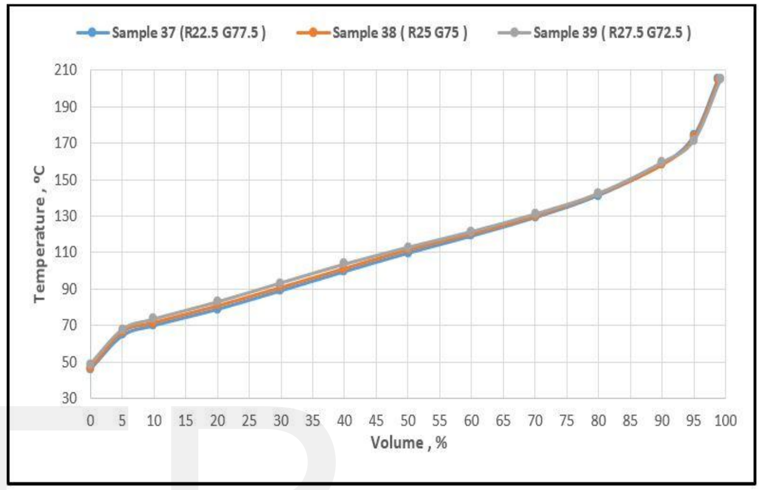

Fig. 21 ASTM Distillation Curves for Gasoline A80-Reformate Blend Samples.

distillation residue is 0.6 vol. %. These results approach to the

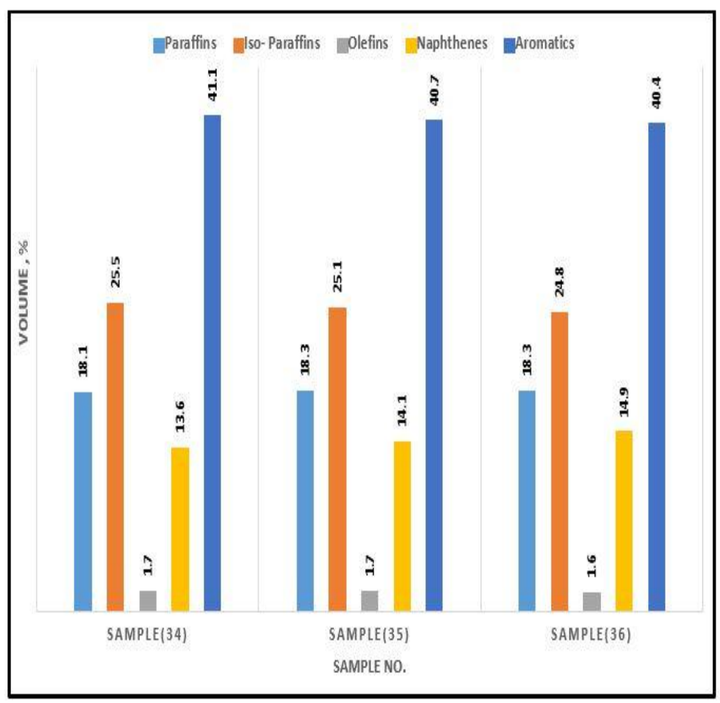

Fig. 18 The Composition of Gasoline A80-Hydrocracked Naphtha blend Samples by Gas Chromatography.

Table 5 Physico-chemical Characteristics of Gasoline A80-Reformate Blend Samples.

Test	Method	Units	Sample No.		
			Sample 37	Sample 38	Sample 39
		composition	$R_{22.5}G_{77.5}$	$R_{25}G_{75}$	$R_{27.5}G_{72.5}$
Density at 15 °C	ASTM D4052	Kg/m³	759.3	762.0	765.8
Reid Vapor Pressure	ASTM D5191	kPa	39	37	35
RON	ASTM D2699		91.6	92	**92.2**
MON	ASTM D2700		81.7	82.6	83
PON	(R+M)/2		86.65	87.3	87.6
Distillation at 100 °C	ASTM D86	Vol. %	41	39.1	38.6
at 150 °C		Vol. %	85	84.8	84.6
at FBP		°C	205.3	204.5	205.0
Distillation Residue		Vol. %	1	0.9	0.6
composition	ASTM D6729				
Paraffins		Vol. %	15.4	15.1	14.7
Iso- Paraffins		Vol. %	36.3	37.6	39.3
Olefins		Vol. %	1.7	1.7	1.7
Naphthenes		Vol. %	10.1	9.9	9.7
Aromatics		Vol. %	36.6	35.7	**34.6**
oxygenates		Vol. %	0.0	0.0	0.0
Benzene		Vol. %	1.3	1.4	**1.4**
Toluene		Vol. %	10.1	10.4	10.8
Ethyl benzene		Vol. %	2.2	2.3	2.4
m-Xylene		Vol. %	5.5	5.7	6.0
p-Xylene		Vol. %	2.3	2.4	2.5
o-Xylene		Vol. %	3.1	3.2	3.3

standard European regulations (Euro-6).

3.4.4 Gas Chromatography (PIONA)

Figure 22 shows the composition of gasoline A80-reformate blend samples by Gas Chromatography. It illustrates the percentages of parrafins, iso-parrafins, aromatics, naphthenes and olefins. Clearly, the aromatic percentages in R22.5, R25 and R27.5 are 41.1, 40.7 and 40.4 vol. % respectively. Finally, the optimum sample is selected according to less one in the aromatic content (R27.5).

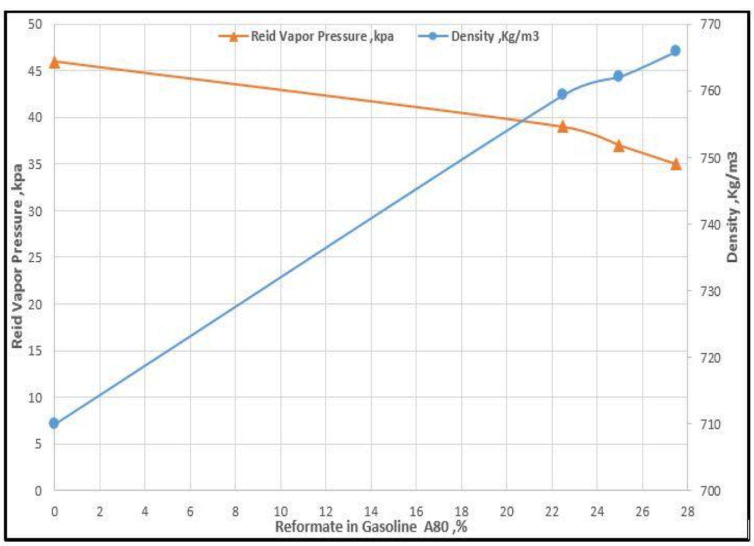

Fig. 20 Density and Reid Vapor Pressure Curves versus Reformate Percent in gasoline A80 Blend.

3.5 Physico-chemical Characteristics of Gasoline A80-Isomerate Blend Samples

Different percentages of Isomerate is added to gasoline A80 and observe the effect of each percent on gasoline A80. The percentage of isomerate are 2.5, 5, and 7.5 vol. % respectively.

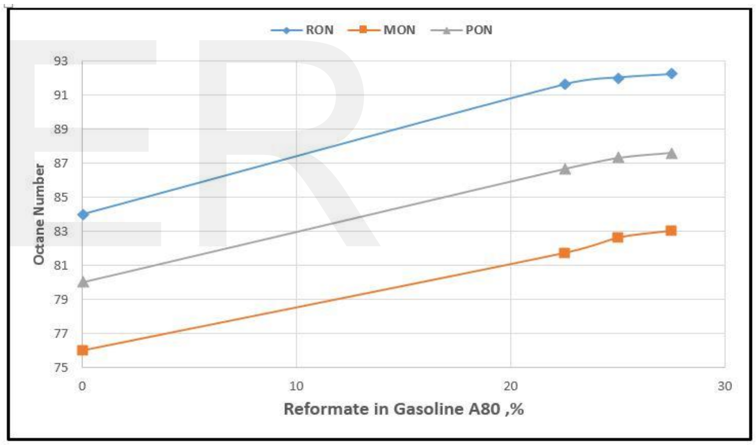

Fig. 19 Relationship between Octane Numbers and Gasoline A80-Reformate blends.

Some measurements are made such as Reid Vapor Pressure, density, research octane number, motor octane number, ASTM distillation, PIONA, and benzene content according to ASTM methods. Table 6 shows physico-chemical characteristics of gasoline A80-isomerate blends. It illustrates density, RVP, RON, MON, PON, ASTM distillation and PIONA for them. The optimum selected sample contains the minimum percent of aromatics (34.6 vol. %). Moreover, the benzene content in this sample is 1.4 vol. %. At the same time, volume percentages at 100 °C and 150 °C are 38.6 and 84.6 vol. % respectively. In addition, the FBP and distillation residue is 205 °C and 1.0 vol. % respectively.

3.5.1 Octane Number Measurement

Research octane number, Motor octane number, and Posted octane number are measured when isomerate is added to gasoline A80. Figure 23 represents the relationship between octane numbers and gasoline A80-reformate blends. The octane numbers (RON, MON and PON) increase up to 2.5 vol. % and decrease continuously with increasing percentages of isomerate. The Research octane number for I2.5, I5 and I7.5 is 86.2, 85.7 and 84.2 respectively. At the end, the optimum sample is I2.5 which has RON, MON and PON is 86.2, 78.9 and 82.55 respectively.

3.5.2 Density and Reid Vapor Pressure

Figure 24 illustrates the density and Reid vapor pressure curves versus Isomerate percent in gasoline A80. It shows that the density values increase up to 2.5 vol. % and thus Reid vapor pressure values decrease until 2.5 vol. %. On the other hand, the density values after 2.5 vol. % decrease while Reid vapor pressure values increase. The density percentages of I2.5, I5 and I7.5 are 738.9, 737.3 and 735.5 Kg/m^3 and its Reid vapor pressure values are 45, 47 and 47 kPa respectively. The density and Reid vapor pressure of the optimum sample are 738.9 kg/m^3 and 45 kPa respectively.

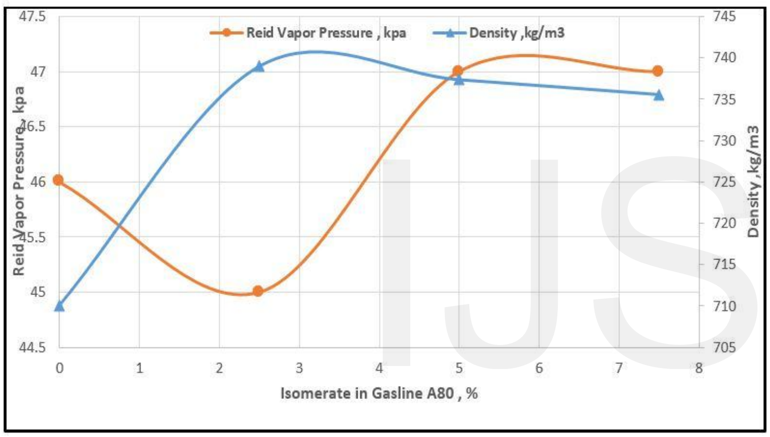

Fig. 24 Density and Reid Vapor Pressure Curves versus Isomerate Percent in Gasoline A80 Blend.

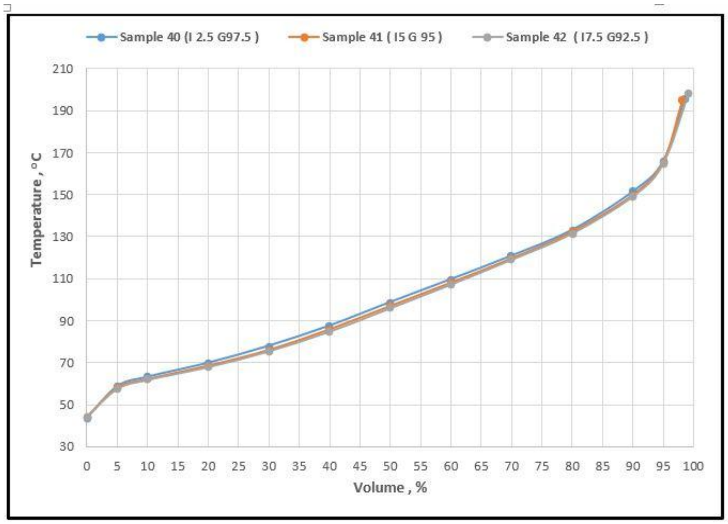

Fig. 25 ASTM Distillation Curves for Gasoline A80-Isomerate Blend Samples.

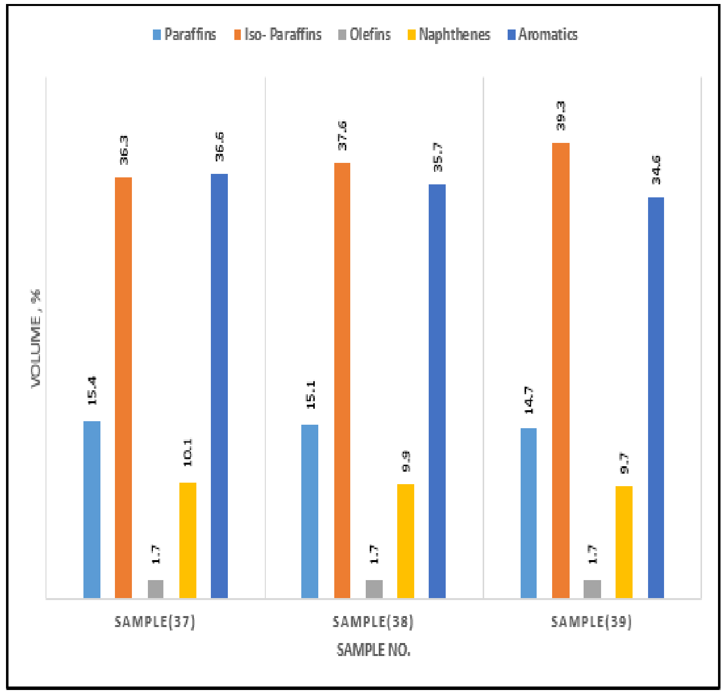

Fig. 22 The Composition of Gasoline A80-Reformate blend samples by Gas Chromatography.

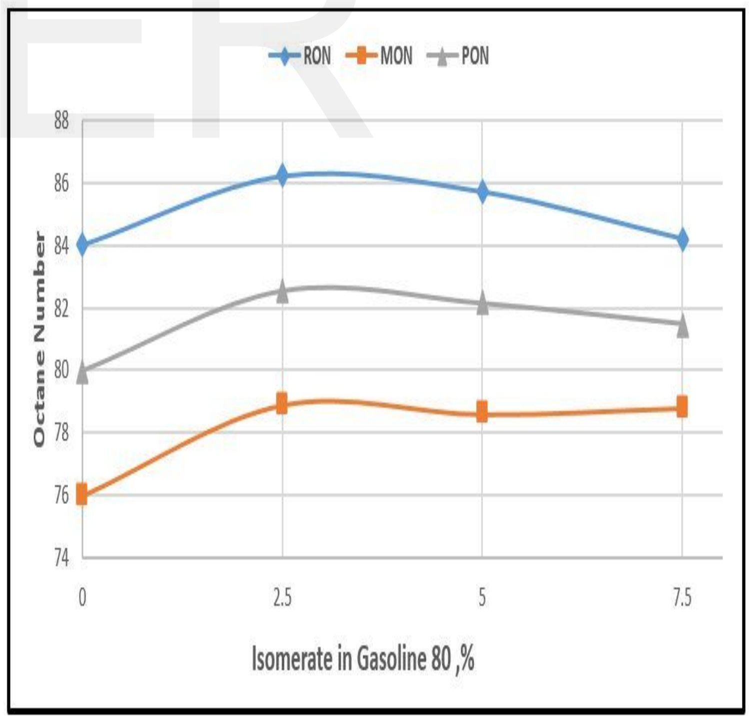

Fig. 23 Relationship between Octane Numbers and Gasoline A80-Isomerate blends

Table 6 Physico-chemical Characteristics of Gasoline A80-Isomerate Blend Samples.

Test	Method	Units	Sample No.		
			Sample 40	Sample 41	Sample 42
composition			$I_{2.5}G_{97.5}$	I_5G_{95}	$I_{7.5}G_{92.5}$
Density at 15 °C	ASTM D4052	Kg/m³	738.9	737.3	735.5
Reid Vapor Pressure	ASTM D5191	kPa	45	47	47
RON	ASTM D2699		**86.2**	85.7	84.2
MON	ASTM D2700		78.9	78.6	78.8
PON	(R+M)/2		82.55	82.15	81.5
Distillation at 100 °C	ASTM D86	Vol. %	51	51.6	52
at 150 °C		Vol. %	89.6	90.1	90.3
at FBP		° C	195.1	194.8	198.4
Distillation Residue		Vol. %	1.0	1.0	0.6
composition	ASTM D6729				
Paraffins		Vol. %	17.3	17.1	17.0
Iso- Paraffins		Vol. %	25.6	24.9	24.4
Olefins		Vol. %	1.9	1.7	1.7
Naphthenes		Vol. %	12.2	12.5	12.3
Aromatics		Vol. %	**43.1**	43.8	44.6
oxygenates		Vol. %	0.0	0.0	0.0
Benzene		Vol. %	**0.9**	0.9	0.9
Toluene		Vol. %	7.2	7.0	6.9
Ethyl benzene		Vol. %	1.6	1.5	1.5
m-Xylene		Vol. %	4.2	3.9	3.8
p-Xylene		Vol. %	1.7	1.6	1.6
o-Xylene		Vol. %	2.3	2.2	2.2

3.5.3 ASTM Distillation

Figure 25 shows ASTM Distillation curves for gasoline A80 - isomerate blend samples. The optimum selected sample is I2.5 and the Volumes of it at 100 oC and 150 °C are 51 and 89.6 vol. % respectively. In addition, the FBP of it is 195.1°C and its distillation residue is 1 vol. %. These results approach to the standard European regulations (Euro-6).

3.5.4 Gas Chromatography (PIONA)

Figure 26 shows the composition of gasoline A80-Isomerate blend samples by Gas Chromatography. It illustrates the percentages of parrafins, iso-parrafins, aromatics, naphthenes and olefins. Clearly, the aromatic percentages in I2.5, I5 and I7.5 are 43.1, 43.8 and44.6 vol. % respectively. Finally, the optimum sample is selected according to less one in the aromatic content (I2.5).

3.6 Optimum Sample relative to gasoline A80

The optimum sample which has a composition (E 7.5 C 3.75 H14 R27.5 I 2.5 G44.75) is prepared to determine the density, Reid vapor pressure, RON, MON ,PON, ASTM Distillation and PIONA. The data is tabulated in Table 7 which demonstrates the optimum sample relative to gasoline A80.

3.6.1 Physico-chemical Characteristics of the Optimum Sample relative to Gasoline A80

Table 8 illustrates the physico-chemical characteristics of the optimum sample relative to gasoline A80. It illustrates the values of density, RVP, RON, MON, PON, ASTM distillation and PIONA for them. The optimum selected sample contains percentage of aromatics (39.5 vol. %). Moreover, the benzene content in this sample is (1.1 vol. %). In the same sample, volumes at 100 °C and 150 °C are 54.5and 84.5 vol. % respectively. In addition, the FBP is 199.6 °C and the distillation residue is 1.3 vol. %. Moreover, the density, RON, MON, PON and RVP values are 734.4 kg/m3, 91.3, 84.1, 87.7 and 44.9 kPa respectively. These results match with standard European regulations (Euro-6) [20] except the percentages of aromatics is in the range of Euro-3. Therefore, the optimum sample in the overall case exactly meet the conditions of Euro-3[21] and approach to Euro-6 regulations. Finally, upgrading for gasoline A80 is achieved to obtain gasoline A92 as an environmental gasoline (It is the best solution in the short run).

3.6.2 ASTM Distillation

Figure 27 illustrates ASTM distillation curve for selected refinery gasoline -blend samples. There are three points are taken on the distillation curve to compare with the standard European regulations (Euro-6). These points are the volume percent at 100 °C and 150 °C and the FBP temperature of the optimum sample. The volumes at 100 °C and 150 °C are 54.5 and 84.5 vol. % respectively and the FBP is 199.6 °C. In addition, the distillation residue is 1.3 vol. %. These results approach to the standard European regulations (Euro-6).

Gasoline A80 which has a lot of pollutants and high percentage of aromatic and benzene content. Therefore, it is upgraded to approach to gasoline A92 and thus a new blend is made for creating an environmental gasoline A 92 according to Euro-6 (EN 228). Finally, the composition of an environmental gasoline (a new blend) contains mainly 39.5 vol. % aromatic content, 28.9 vol. % isoparaffins and 1.1 vol. % benzene content.

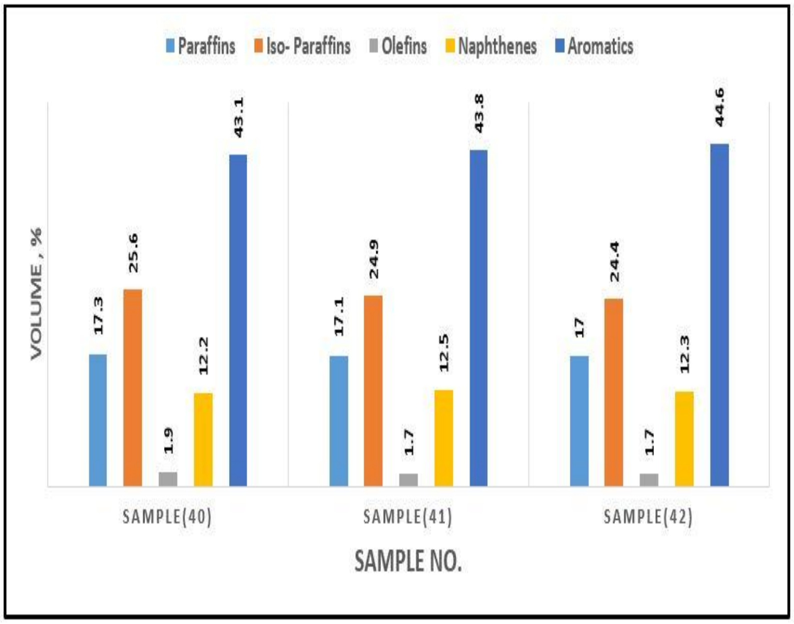

Fig. 26 The Composition of Gasoline A80-Isomerate blend Samples by Gas Chromatography.

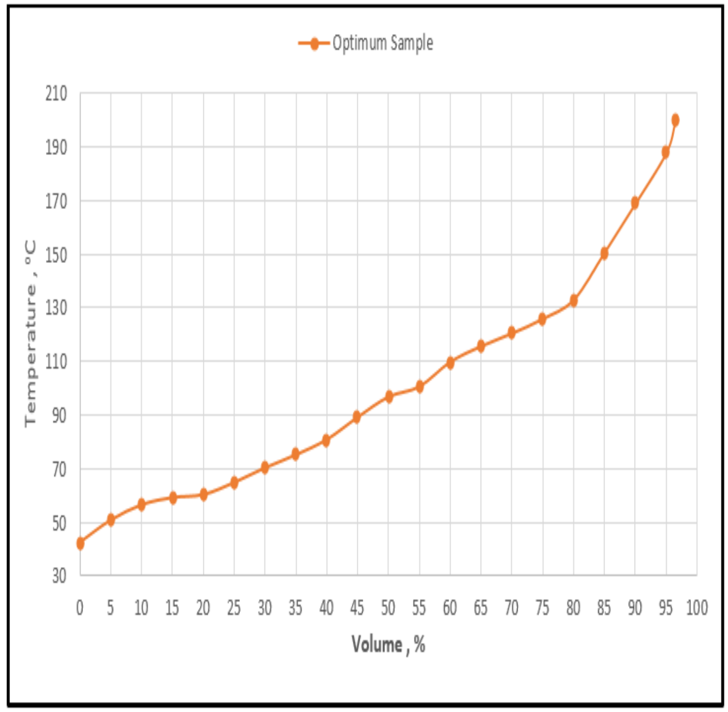

Fig. 27 ASTM Distillation curve of Optimum Sample relative to gasoline A80.

Table 7 The Optimum Sample relative to gasoline A80.

Blend stock	Optimum Percent
Ethanol	7.5
Coker	3.75
Hydrocracker Naphtha	14
Reformate	27.5
Isomerate	2.5
Gasoline 80	44.75

4 CONCLUSIONS

The following conclusions could be drawn from this study:

1. Gasoline A80 which has a lot of pollutants and high percentage of aromatic and benzene content. Therefore, it is upgraded to approach to gasoline A92 and thus a new blend is made for creating an environmental gasoline A 92 according to Euro-6 (EN 228).
2. The optimum sample contains ethanol, reformate, isomerate, Coker naphtha and hydrocracked naphtha with the percentages of 7.5, 27.5, 2.5, 3.75 and 14 Vol. % respectively.

   The optimum selected sample contains the percentage of aromatics (39.5 vol. %). Moreover, the benzene content in this sample is (1.1 vol. %). At the same time, volumes at 100 oC and 150 oC are 54.5and 84.5 vol. % respectively. In addition, the FBP is 199.6 oC and the distillation residue is 1.3 vol. %. Furthermore, the density, RON, MON, PON and RVP values are 734.4 kg/m3, 91.3, 84.1, 87.7 and 44.9 kPa respectively.
3. The optimum sample in the overall case exactly meet the conditions of Euro-3 and approach to Euro-6 regulations.
4. An Environmental gasoline provides a great potential benefit to the refinery in view of minimizing operating costs, product quality improvement, safe and healthy living environments.

ACKNOWLEDGMENTS

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Table 8 Physico-chemical Characteristics of the Optimum Sample relative to gasoline A80.

Test	Method	Units	Optimum Sample (43) $E_{7.5}C_{3.75}H_{14}R_{27.5}I_{2.5}G_{44.75}$
Composition			
Density at 15 ºC	ASTM D4052	Kg/m³	734.4
Reid Vapor Pressure	ASTM D5191	kPa	44.9
RON	ASTM D2699		**91.3**
MON	ASTM D2700		**84.1**
PON	(R+M)/2		**87.7**
Distillation at 100 ºC	ASTM D86	Vol. %	54.5
at 150 ºC		Vol. %	84.5
at FBP		ºC	199.6
Distillation Residue		Vol. %	1.3
Composition	ASTM D6729		
Paraffins		Vol. %	17.5
Iso- Paraffins		Vol. %	28.9
Olefins		Vol. %	1.7
Naphthenes		Vol. %	12.4
Aromatics		Vol. %	**39.5**
Oxygenates		Vol. %	7.5
Benzene		Vol. %	**1.1**
Toluene		Vol. %	8.2
Ethyl benzene		Vol. %	1.8
m-Xylene		Vol. %	5
p-Xylene		Vol. %	1.9
o-Xylene		Vol. %	2.5

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