Maximize the Production of Environmental, Clean and High Octane Number Gasoline-Ethanol Blends by using Refinery Products

Abdel-Monem A. El-Bassiouny, Tarek M. Aboul-Fotouh, Tamer M. M. Abdellatief

Abstract— Gasoline produced in Egypt is a low-grade gasoline that contains a high concentration of harmful components that are having a toll on our environment. In addition, those pollutants cause countless diseases and deaths annually to the Egyptian population. This paper investigates the effect of ethanol-gasoline blends on fuel properties characteristics using standard laboratory methods. Fuel properties tests are conducted for density, RVP, ASTM distillation, RON, MON, PON, PIONA, and benzene content of ethanol-gasoline blends with different percentages of ethanol. 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. Fuel properties test-results showed that blends densities increased continuously and linearly with increasing percentage of ethanol, while Reid Vapor pressures decreased. Furthermore, ASTM distillation curves for blends are found to be lower than pure gasoline fuel. The tested blends Octane rating based on Research Octane Number (RON) increased continuously and linearly with increasing the percentage of ethanol. Results from this study will be valuable on the assessment of the suitability of ethanol-gasoline blends as bio-fuel for the automotive industry to cover for the country demands.

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

1 INTRODUCTION

Fuel additives are very important since many of these additives can be added to the fuel in order to enhance its efficiency and its performance. The main fuel resulting found to be an increasingly important alternative to petroleum is bio-fuel. It is biodegradable, and produces less air pollution than the fossil fuel. The fossil fuel exhaust is carcinogen since the use of bio-fuel has been found to reduce risks of cancer because it reduces the production of cancer-causing compounds, such as carbon monoxide. Bio-fuel also produces less greenhouse gases such as CO_2. When either bio-fuel or petroleum is burned, the carbon content of the fuel returns to the atmosphere as CO_2. Plants grown to make ethanol for bio-fuel draw CO_2 out of the atmosphere for photosynthesis, causing a recycling process that result in less accumulation of CO_2 in the atmosphere [1].

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Ethanol was the first fuel among the alcohols to be used to power vehicles .Henry Ford presented it as the fuel of choice for his automobiles during their earliest stages of development [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.

Many researchers have reported on gasoline-ethanol blends properties, engine performance, and emissions characteristics. Muzíková [3] studied the effect of ethanol up to 10 vol. %, ETBE up to 10 vol. % and hydrocarbon composition over volatility and ASTM distillation. In addition, Petre [4] used two classical gasolines with different compositions and properties, and with proportions ranging from 2 to 10 vol. % of ethanol and other alcohols, presents experimental results regarding the effect of the blend with alcohol on the RVP, ASTM distillation curves and evaporated percent at 70 ^{o}C. In another paper [5] by the same author and used two classical gasolines with different compositions and properties, and with proportions ranging from 4 to 15 vol. % of ETBE and other ethers, she presents experimental results regarding the effect of the blend with alcohol on the RVP, ASTM distillation curves and vapor lock index. Pumphrey [6] offered a simple method to successfully predict vapor pressures of gasoline–alcohol mixtures and validate them with blends of gasoline with different oxygenates (0–100) vol. %. Furthermore, French [7] illustrated the effect of the addition of ethanol to gasoline on the RVP, ASTM distillation curves (0–10) vol. %, the Vapor/Liquid ratio, the Vapor Lock Index, the Drivability Index, the phase separation and the material compatibility. Menezes [8] analyzed the effect of the addition of an azeotropic ETBE/ethanol mixture in two gasolines (0–17) vol. % on the RVP, the distillation curve, the density and the octane number. Khamis et al. [9] focused on Some production recipes of stock motor gasoline of A92, A95 and A98 commercial grade using the component streams manufactured in Lukoil-Neftochim Bourgas refinery units and meeting all requirements of the EN228 have been proposed the gasoline blending provides a great potential benefit to the refinery in view of minimizing operating costs and product quality improvement. Yamin et al. [10] investigated the effect of ethanol addition to low Octane Number gasoline, in terms of calorific value, Octane Number, compression ratio at knocking and engine performance. They blended locally produced gasoline (Octane Number 87) with six different percentages of ethanol, namely 10, 15, 20, 25, 30, and 35 vol. %. They found that the Octane Number of gasoline increased continuously with the ethanol percentages in gasoline. They reported that the ethanol was an effective compound for increasing the value of the Octane Number of gasoline. Kheiralla et al. [1] investigated the effect of ethanol-gasoline blends which used as alternative fuel for variable speed spark ignition up to 35 vol. % blends without engine modification on fuel properties characteristics of a variable speed SI engine. The properties of ethanol-gasoline blends are determined such as density, API gravity, viscosity, flash and fire point, cloud point, heat value, ASTM distillation and Octane rating based on Research Octane Number (RON) for blends compare them with those of pure gasoline fuel. Johnson and Schramm [11] studied the low-temperature miscibility of ethanol gasoline-water blends in flex fuel applications at -25 and -2°C. It was found that the blend can be successfully used without phase separations within the tested temperature range. Abdel-Rahman [12] tested 10, 20, 30 and 40 vol. % ethanol of blended fuels in a variable-compression-ratio of the engine. They found that the increase of ethanol content increases the octane number but decreases the heating value. The 10 vol. % addition of ethanol had the most obvious effect on increasing the octane number. Under various compression ratios of engine, the optimum blend rate was found to be 10 vol. % ethanol with 90 vol. % gasoline. In other study, Hakan Bayraktar [13] investigated the effects of ethanol addition to gasoline 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. However, theoretical comparisons have shown that the blend containing 16.5 vol. % ethanol was the most suited blend for SI engine. Kim et al. [14] estimated that the potential for ethanol production is equivalent to about 32% of the total gasoline consumption worldwide, when used in 85 vol. % ethanol in gasoline for a midsize passenger vehicle. Altun et al. [15] studied the effect of 10 vol. % and 10 vol. % ethanol and methanol blending in unleaded gasoline on engine performance and exhaust emission. Results showed that M10 and E10 blended fuels demonstrated the best result in the exhaust emission. The HC emission of M10 and E10 are reduced by 13 % and 15 % and the CO emissions by 10.6. % and 9.8 %, respectively. CO_2 emission is increased for M10 and E10 compared with unleaded gasoline.

The purpose of this study is to investigate the effect of ethanol-gasoline blends on fuel properties characteristics of a variable speed SI engine. Some experimental are done to determine the properties of gasoline-ethanol blends such as density, Reid Vapor Pressure, RON, MON, PON and ASTM distillation, PIONA and benzene content and compare them with those of pure gasoline fuel. 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. production of environmental gasolines A95 and A98 according to Euro-6 regulations, is accomplished by using the following refinery fractions in Egypt:

1. Straight Run Naphtha.
2. Reformate.
3. Isomerate.
4. Hydrocracked Naphtha.
5. Coker Naphtha.
6. Ethanol.

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 and 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 following physico-chemical characteristics such as the density, RVP, ASTM distillation, RON, MON, PON, PIONA and benzene content. Figs 1-6 list various apparatus employed in the determination of these fuel properties. The density of each tested sample is measured by density meter apparatus (ASTM 4052) [16]. The distillation curve is determined by ASTM distillation device in accordance with ASTM D86 [17]. The Reid vapor pressure is determined by Reid vapor pressure device in accordance with ASTM D 5191[18]. The blends Octane rating is determined by a Cooperative Fuels Research (CFR) Engine and octane meter apparatus for research octane number (ASTM D2699)[19] and motor octane number (ASTM D 2700) [20]. The Hydrocarbon types content is obtained by Gas chromatography in accordance with ASTM D 6839 [21].

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.

3.1 Physico-chemical Characteristics of Refinery Gasoline-Blend Samples

Acquiring different sources of blend stocks are completely blended in order to produce different refinery gasoline - blend samples which have different composition of Straight Run Naphtha, Reformate, Isomerate, Coker Naphtha and Hydrocracked Naphtha. Those blends are tabulated in Table 1. The Gas Chromatography Device uses to know the percentages of n-paraffins, iso-paraffins, olefins, naphthenes, aromatics (PIONA) and benzene content of each blend stock sample, as shown in Table 2. Three samples are chosen according to European Regulations Euro-6 and directly complete physico-chemical characteristics are achieved to select an optimum gasoline blend sample for experimental works as a blend with ethanol.

The Selected samples ; sample 4, sample 9 and sample 19; are chosen based on the percentages of aromatics, isoparrafins, olefins and benzene content in each of three samples. These samples contain the smallest percent of aromatics which represent a content approach to Euro- 6 Regulations and the percentages of aromatics content of them are 34.1, 31.9 and 34.8 vol. % respectively. In addition, the benzene content of these samples is less than 1 vol. %. Moreover, the standard percentage of aromatic content is 35 by vol. % including 1 vol. % benzene as a maximum percent; Euro-6.

3.2 Physico-chemical Characteristics of three Samples Prepared for Euro-6

Table 3 illustrates physico-chemical characteristics of the selected three samples prepared for Euro-6. It shows density, RVP, RON, MON, PON, ASTM distillation and PIONA for them. The optimum selected sample contains the maximum percent of isoparrafins (29.4 vol. %) and the minimum percent of aromatics (31.9 vol. %). Moreover, the benzene content in this sample is a minimum percent (0.61 vol. %). In the same sample, volumes at 100 ^{o}C and 150 ^{o}C are 49 and 89 vol. % respectively and the FBP is 190.4 ^{o}C. In addition, the sample has a good start octane number for all blends.

3.2.1 ASTM Distillation Curves of Selected Samples

ASTM distillation curve shows the percentage of hydrocarbons that boil and distill at various temperatures and helps us to determine the volatility of each sample and thus gives us information on how to handle those samples and even store them.

The main factor to understand here is what the sample is composed off. For example, if the sample contains heavier contents, then a greater temperature would be required to evaporate it. This would then mean that different volume percent would be achieved at higher temperatures. On the other hand, lighter components in samples would require less heat in order for them to evaporate and thus would for example have a lower IBP.

Figure 7 represents ASTM distillation curves for selected refinery gasoline - blend samples. There are three points are taken on the distillation curve to compare the distillation among the three different samples.

These points are the volume percent at 100 ^{o}C and 150 ^{o}C and the FBP temperature of the optimum sample. Therefore, volumes at 100 ^{o}C and 150 ^{o}C are 49 and 89 vol. % respectively and the FBP is 190.4 ^{o}C. In addition, the distillation residue is 1.2 vol. %.

Sample (19) has components lighter than sample (9) and (4) because it has a high content of isomerate. In other words, isomerate is lighter than any components. The percentages of Isomerates in samples19, 9 and 4 are 24, 19 and 18 vol. % respectively, as shown in Figure 8.

Fig.1 Gas Chromatography Apparatus.

Fig.4 Cooperative Fuels Research (CFR) Engine.

Fig.2 Density Meter Apparatus.

Fig.5 Reid Vapor Pressure Apparatus.

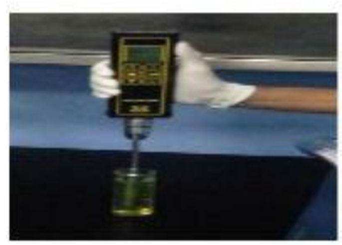

Fig.3 Reid Vapor Pressure Apparatus.

Fig.6 Reid Vapor Pressure Apparatus.

TABLE 1 Refinery Gasoline - Blend Samples.

Source	Blend stock	Sample Number																			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Crude Distillation	Straight Run Naphtha (N)	7	10	12	18	16	13	9	15	17	15	12	18	13	13	18	14	9	5	11	13
Upgrading units	Reformate (R)	58	60	52	35	59	49	53	39	32	55	62	48	60	44	37	39	57	60	34	49
	Isomerate (I)	10	15	16	18	9	16	16	18	19	9	10	8	11	15	19	19	9	10	24	15
Conversion units	Hydrocracker Naphtha (H)	22	10	17	25	14	17	19	24	28	19	11	23	13	23	23	26	24	20	27	19
	Coker Naphtha(C)	3	5	3	4	2	5	3	4	4	2	5	3	3	5	3	2	1	5	4	4

TABLE 2 Gas Chromatography Analysis of Refinery Gasoline -Blend Samples.

Group	Sample Number																				European standard Regulation
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Euro-6 (NEN-EN 228)
Composition	$N_{7}R_{58}I_{10}H_{22}C_{3}$	$N_{10}R_{60}I_{15}H_{10}C_{5}$	$N_{12}R_{52}I_{16}H_{17}C_{3}$	$N_{18}R_{35}I_{18}H_{25}C_{4}$	$N_{16}R_{59}I_{9}H_{14}C_{2}$	$N_{13}R_{49}I_{16}H_{17}C_{5}$	$N_{9}R_{53}I_{16}H_{17}C_{3}$	$N_{15}R_{39}I_{18}H_{24}C_{4}$	$N_{17}R_{32}I_{19}H_{28}C_{4}$	$N_{15}R_{55}I_{9}H_{19}C_{2}$	$N_{12}R_{62}I_{10}H_{11}C_{5}$	$N_{18}R_{48}I_{8}H_{23}C_{3}$	$N_{13}R_{60}I_{11}H_{13}C_{3}$	$N_{13}R_{44}I_{15}H_{23}C_{5}$	$N_{18}R_{37}I_{19}H_{23}C_{3}$	$N_{14}R_{39}I_{19}H_{26}C_{2}$	$N_{9}R_{57}I_{9}H_{24}C_{1}$	$N_{5}R_{60}I_{10}H_{20}C_{5}$	$N_{11}R_{34}I_{24}H_{27}C_{4}$	$N_{13}R_{49}I_{15}H_{19}C_{4}$	
Paraffins	14.85	14.68	16.08	20.30	15.76	17.17	15.46	19.14	20.20	16.37	15.01	18.27	15.16	18.24	19.73	18.56	15.06	14.56	18.70	17.08	-
Iso-Paraffins	25.15	22.33	24.95	27.70	24.27	24.95	25.07	27.66	29.40	25.5	22.68	26.87	23.59	26.64	28.05	28.3	26..06	24.14	29.10	25.54	-
Olefins	2.61	3.68	2.65	2.70	2.1	3.45	2.67	2.84	2.60	2.11	3.52	2.33	2.69	3.29	2.36	1.95	1.75	3.47	2.90	2.98	3-13
Naphthenes	10.32	7.65	10.5	15.20	9.73	10.87	10.43	13.9	15.90	11.08	8.09	12.96	8.94	12.78	14.52	14.48	11.21	9.32`	14.50	11.37	-
Aromatics	47.07	51.66	45.83	34.10	48.04	43.56	46.38	36.36	31.90	44.95	50.6	39.56	49.62	39.05	35.33	36.61	45.92	48.5	34.80	43.03	29-35
Oxygenates	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-
Benzene	0.75	0.78	0.68	0.69	0.77	0.64	0.69	0.51	0.61	0.72	0.81	0.62	0.78	0.57	0.48	0.51	0.74	0.78	0.66	0.64	≤1

TABLE 3 Physico-chemical Characteristics of Selected Samples according to Euro-6.

Test	Method	Units	Prepared Samples for Euro-6		
			Sample 4	Sample 9	Sample 19
Composition			$N_{18}R_{35}I_{18}H_{25}C_4$	$N_{17}R_{32}I_{19}H_{28}C_4$	$N_{11}R_{34}I_{24}H_{27}C_4$
Density at 15 °C	ASTM D4052	Kg/m3	746.8	740.2	740.2
Reid Vapor Pressure	ASTM D5191	kPa	44	44	48
RON	ASTM D2699		88.9	**85.9**	85.2
MON	ASTM D2700		80.2	**78.7**	78.4
PON	(R+M)/2		84.55	**82.3**	81.8
Distillation at 100 °C	ASTM D86	Vol. %	46	49	51
at 150 °C		Vol. %	89	89	90
at FBP		°C	194.8	190.4	191.4
Composition (PIONA)	ASTM D6729				
Paraffins		Vol. %	20.30	20.20	18.70
Iso- Paraffins		Vol. %	27.70	**29.40**	29.10
Olefins		Vol. %	2.70	2.60	2.90
Naphthenes		Vol. %	15.20	15.90	14.50
Aromatics		Vol. %	34.10	**31.90**	34.80
oxygenates		Vol. %	0.00	0.00	0.00
Benzene		Vol. %	0.69	**0.61**	0.66
Toluene		Vol. %	8.7	7.6	7.9
Ethyl benzene		Vol. %	1.8	1.5	1.6
m-Xylene		Vol. %	4.1	3.5	3.7
p-Xylene		Vol. %	1.7	1.4	1.5
o-Xylene		Vol. %	2.3	1.9	2.0

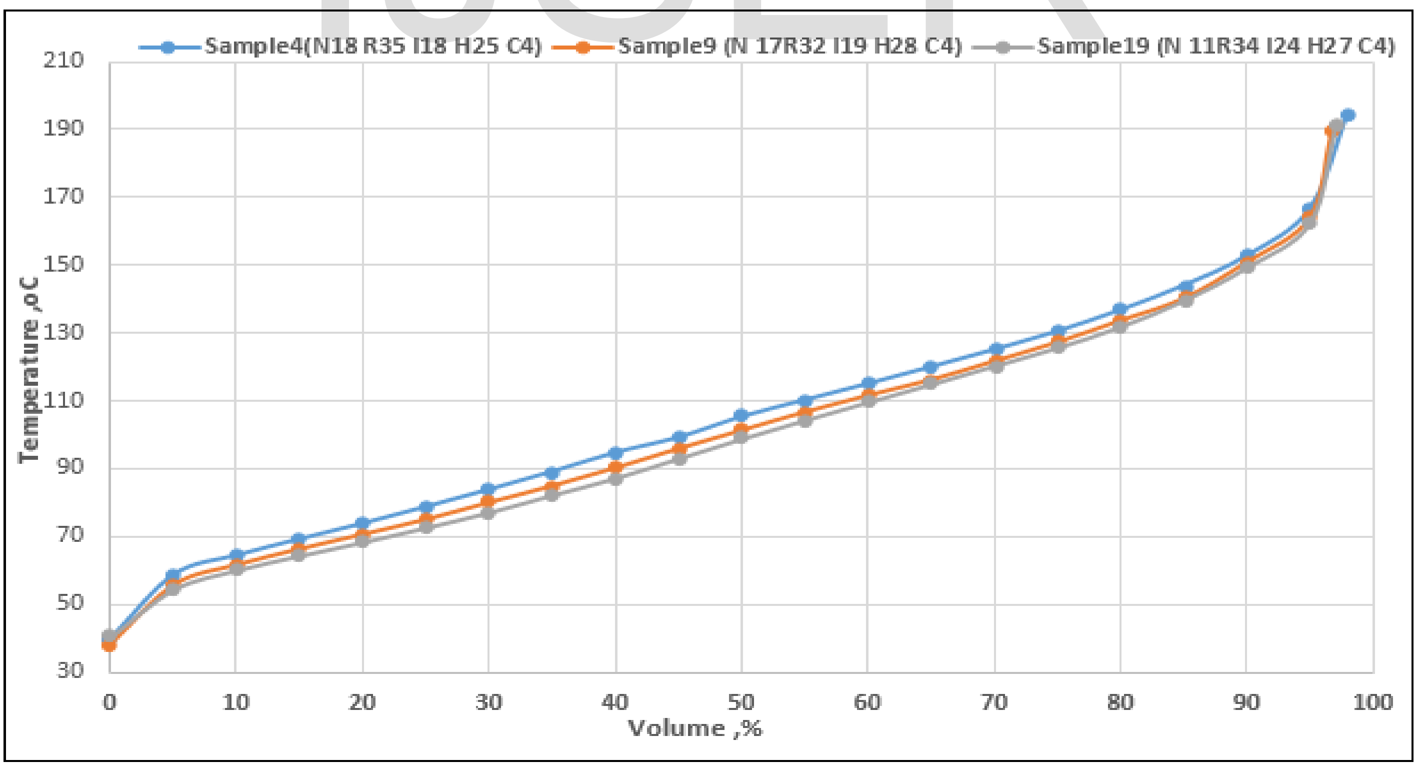

Fig.7 ASTM Distillation Curves for Different Gasoline – Blend Samples.

3.2.2 Gas chromatography (PIONA)

It is a device which used for determining the amount of Parrafins, Olefins, Aromatics, isoparaffins, Naphthenes and benzene content. The comparison among the three samples is based on the aromatics, Iso-paraffin and benzene content. The highest percentage of aromatic content in the sample will increase the octane number but it affects on our environment negatively.

The aromatics in sample (4), sample (9) and sample (19) are 34.10, 31.9 and 34.8 vol. % respectively. The optimum percent of aromatics is chosen according to the least percent in the three samples; sample (9).

The isoparaffins in sample (4), sample (9) and sample (19) are 27.7, 29.4 and 29.10 vol. % respectively. The optimum percent of isoparaffins is selected based on the highest percentage in the three samples; sample (9).

The Figure 9 explains the composition analysis of selected refinery gasoline-blend samples by gas chromatography (PIONA).The benzene content in the optimum sample should be less than 1 % by volume according to Euro-6 regulations. If the percentage of benzene content is more than 1% by vol. %, the sample is considered off-specification. Therefore, the production of environmental gasoline requires the percentages of benzene content should be decreased as possible.

For more explanation, the benzene contents in sample (4), sample (9), and sample (19) are 0.69, 0.61 and 0.66 vol. % respectively and thus the optimum sample is selected based on the least percentages of benzene ; sample(9).

From the previous Tables and Figures, the Sample (9) represents the optimum sample because it contains benzene content 0.61 vol. %, aromatics content 31.9 vol. % and isoparaffins 29.4 vol. %. It is used to produce environmental gasoline according to Euro-6 regulations by adding different percentages of oxygenated compounds.

An oxygenated compound (ethanol) is added to gasoline pool (sample (9)) to produce an environmental gasoline with high octane number. The different percentages of ethanol added to sample (9) are E0, E2.5, E5, E10, E15 and E20 respectively.

3.3 Physico-chemical Characteristics of Gasoline-Ethanol Blend Samples

Table 4 demonstrates physico-chemical characteristics of gasoline-ethanol blend samples. It shows density, RVP, RON, MON, PON, ASTM distillation and PIONA for them. The optimum selected samples are samples (23) and (24) for gasolines A 95 and A98 respectively. In the sample (23) , the density at 15 ^{o}C, RVP, RON, MON, PON, aromatics and benzene contents are 740.2 kg/m^3, 57 kPa, 95, 86.1, 90.55, 31.3 vol. % and 0.6 vol. % respectively. In sample(24), the density at 15 ^{o}C, RVP, RON, MON, PON, aromatics and benzene contents are 742.6 kg/m3, 58 kPa, 98, 96, 97, 30.9 vol. % and 0.6 vol. % respectively.

Additions of E2.5 and E5 by volume to gasoline pool are the main target to produce environmental gasolines A95 and A98 according to Euro-6 regulations.

Some recipes for the production of stock gasolines A95 and A98 commercial grade on the basis of component streams produced in refinery units and satisfying all specifications of the European regulation which are elaborated[22]. Thus, the gasoline blending provides a great potential benefit to the refinery in view of minimizing operating costs and product quality improvement.

3.3.1 The Effect of Ethanol Addition on Octane Number

Figure 10 shows the effect of the E% in the fuel blend on the octane numbers. The data are shown for Research Octane Number, Motor Octane Number and the antiknock index or posted octane number (R+M/2).

The more of the ethanol is added to gasoline, the more increasing in octane numbers are achieved to a certain limit and subsequently the octane numbers start to decrease. For more explanation, the starting RON is 85.9 and after adding E2.5, the RON increases to 95. In case of E5 is added to gasoline, the RON increases to 98, and after adding E10 to the gasoline, the RON reaches up to 103. However, in the case of E15 is added to gasoline, the RON starts to decrease to 102 and followed by 97 RON at E20. The decline in octane number refers to exceed the total amount of O_2 the maximum percentages 2.7 vol. % according to Euro-6 regulations.

3.3.2 The Effect of Ethanol Addition on Reid Vapor Pressure and Density

Fuel density is a physical property that affects the fuel economy of a vehicle. When drivers buy fuel in a gas station they pay for the volume acquired but the energy picked up depends on the total mass. The higher the density of the fuel the more the energy acquired.

The densities of E0, E2.5, E5, E10, E15 and E20 are 740.2, 742.6, 744.3, 745.4, 750 and 752.5 kg/m^3 respectively and The Reid Vapor Pressures are 44, 57, 58, 58, 55 and 53 kPa respectively.

The ranges of standard density and Reid vapor pressure according to Euro-6 regulations are from 720 to775 kg/m^3 and from 45 to 60 kPa respectively. These values for the optimum samples, gasolines A95 and A98, are lied in Euro-6 regulations ranges.

The addition of ethanol on gasoline has positive effect through the Reid vapor pressure. Figure 11 shows the Reid vapor pressure and density curves versus different ethanol percentages. In the small concentration of ethanol in gasoline up to 5 % by volume, the Reid vapor pressure increases while in the high concentration more than 5 % by volume, the Reid vapor pressure decreases. The density increases linearly with the addition of ethanol. In the general case, the addition of ethanol to gasoline leads to decrease the Reid vapor pressure and increase the density.

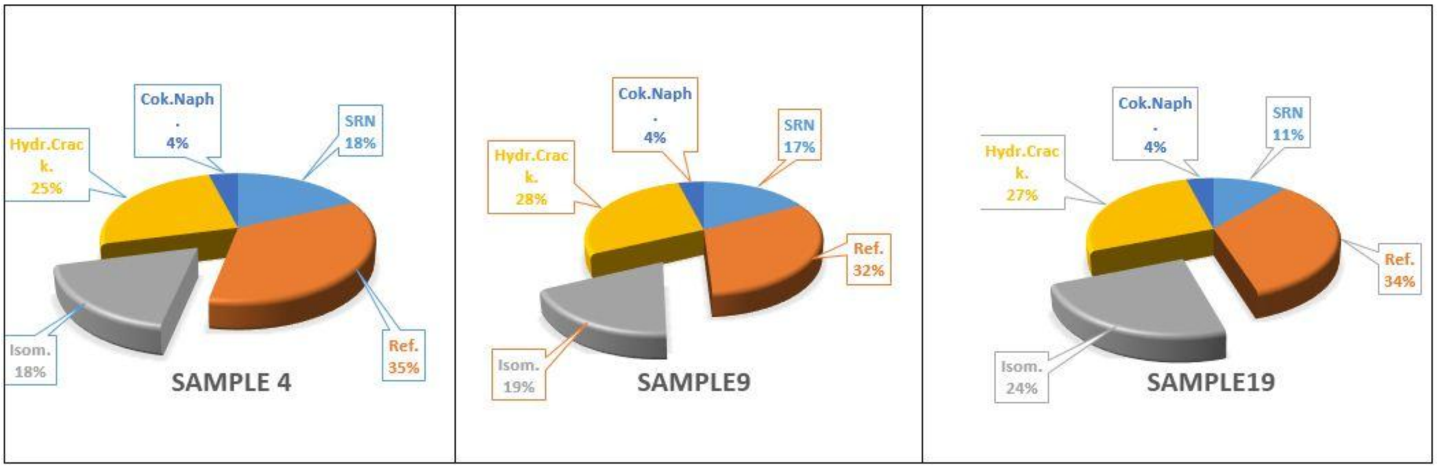

Fig.8 Comparison among Selected Refinery Gasoline - Blend Samples.

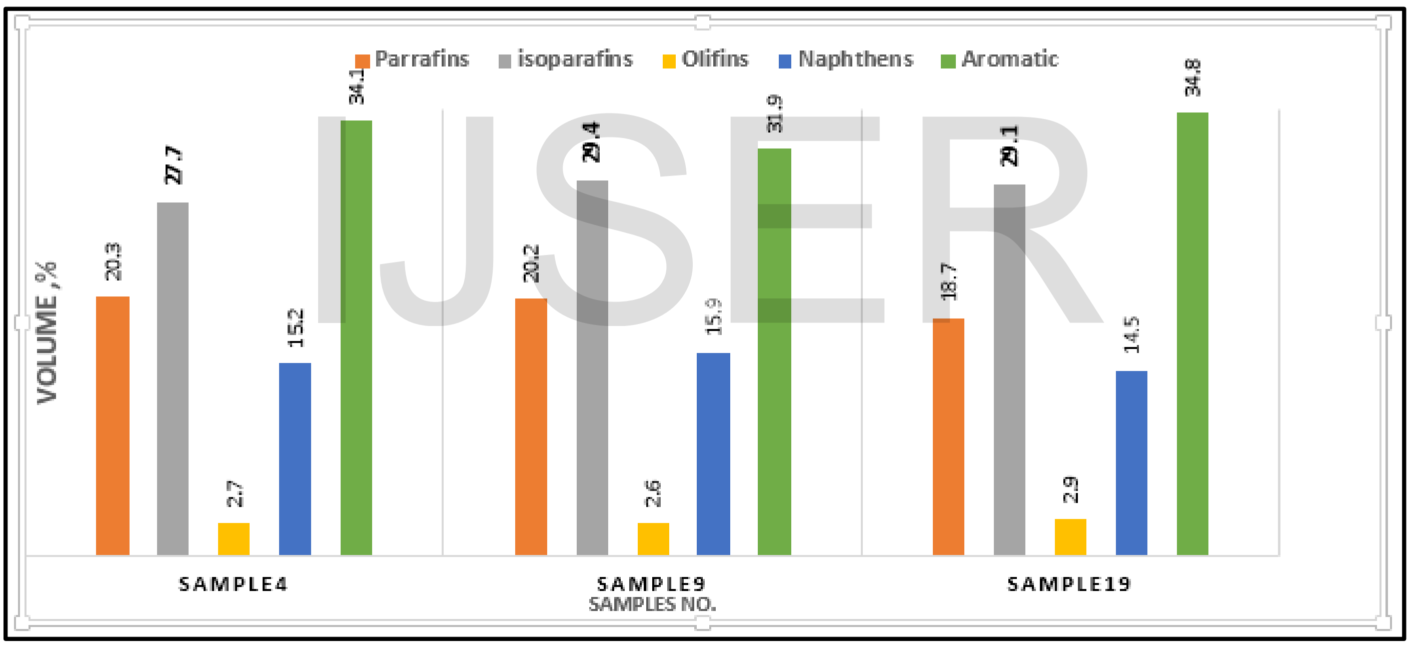

Fig. 9 the Composition Analysis of Selected Refinery gasoline- blend samples by gas chromatography.

3.3.3 The Effect of Ethanol on ASTM Distillation

The ASTM distillation curve profile affects engine behavior significantly. Three parts can be differentiated in the following curves (Fig.12):

- Lighter fractions: from 0% to 40% of distilled volume.
- Medium fractions: from 40% to 80% of distilled volume.
- Heavy fractions: from 80% to 100% of distilled volume.

It has been shown by many previous researchers that the presence of high alcohol percentages in gasoline depresses the distillation curve of fuel, which can cause problem with cold starting and vapor lock. Adding ethanol to gasoline will increase the volatility, decrease the 50% distillation point T50. The results in Figure 13 which shows the distillation curves for gasoline and blends E0, E2.5, E5, E10, E15 and E20.The distilled volumes of E0, E2.5, E5, E10, E15 and E20 at 100 oC are 49, 48.5, 50.7, 54.8, 54.9 and 66 vol. % respectively and at 150 0C are 89, 88.9, 89, 90.4, 87.6 and 91.2vol. % respectively. The FBP of E0, E2.5, E5, E10, E15 and E20 are 190.4, 190.2, 190.1, 188.1, 191.8 and 187 oC respectively. The distillation residue for different percentages of ethanol are 1.2, 1.2, 1.2, 1.2, 1.3 and 1.2 vol. % respectively. Finally, the addition of Ethanol leads to a distortion of the base gasoline's distillation curves.

The standard Euro-6 volumes at 100 °C and 150 °C are 46-71 vol. % and minimum 75 vol. % respectively. In addition, the maximum values of FBP and distillation residue are 210 °C and 2 vol. % respectively. The previous distilled volumes, final boiling point and distillation residue satisfy all specification of Euro-6 ranges.

3.3.4 Gas chromatography (PIONA)

The percentages of parrafins, isoparrafins, olefins, aromatics, naphthenes, and benzene content are determined by Gas chromatography. The comparison among the samples is depended mainly on the percentage of aromatics, isoparrafins and benzene content. Figure 13 demonstrates the composition analysis for gasoline-ethanol blend samples by gas chromatography.

The percentages of aromatics for E0, E2.5, E5, E10, E15 and E20 are 31.9, 31.3, 30.9, 30.3, 29.8 and 29.1vol. % respectively and for isoparaffins are 29.4, 29.1, 28.9, 28.1, 27.8 and 26 vol. % respectively. The standard Euro-6 regulation of aromatics content in the samples should not exceed about 35 vol. %.

The comparison among the samples based on the benzene content which has negative effect on the environmental. The benzene content for E0, E2.5, E5, E10, E15 and E20 are 0.61, 0.6, 0.6, 0.6, 0.59 and 0.56 vol. % respectively .These values are less than 1 vol. % which correspond to the Euro-6 regulations.

New blends are made for the production of environmental gasoline by using an oxygenated compound (ethanol) with A 98 and A 95 which satisfy all specification of Euro-6 regulations. The new blends are friendly environmental and contains the less amount of benzene content.

The composition of environmental gasoline E2.5 (Gasoline A95) contains 31.3 vol. % aromatic content and 29.1 vol. % isoparaffins. Moreover, the composition of environmental gasoline E5 (Gasoline A98) contains 30.9 vol. % aromatic content and 28.9 vol. % isoparaffins.

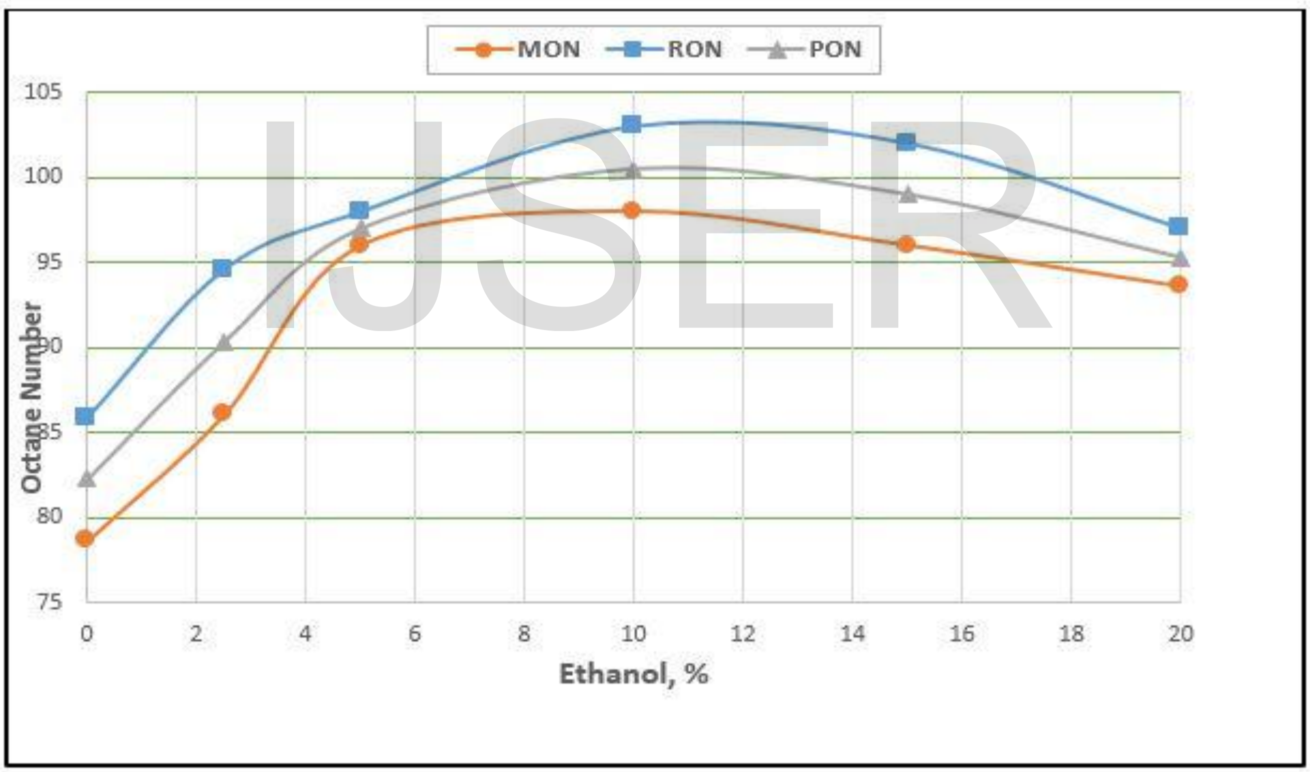

Fig. 10 Relationship between Octane Numbers and Gasoline –Ethanol blends

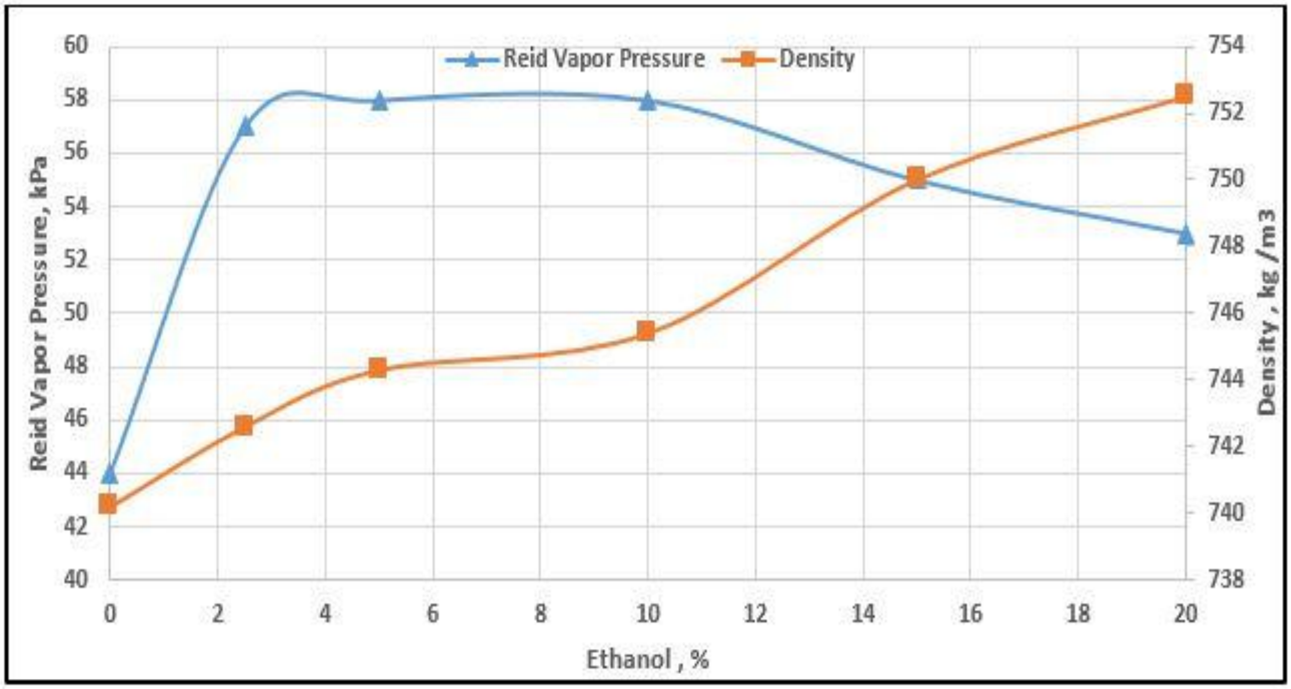

Fig. 11 Density and Reid Vapor Pressure Curve versus Ethanol Percent in Gasoline Blend

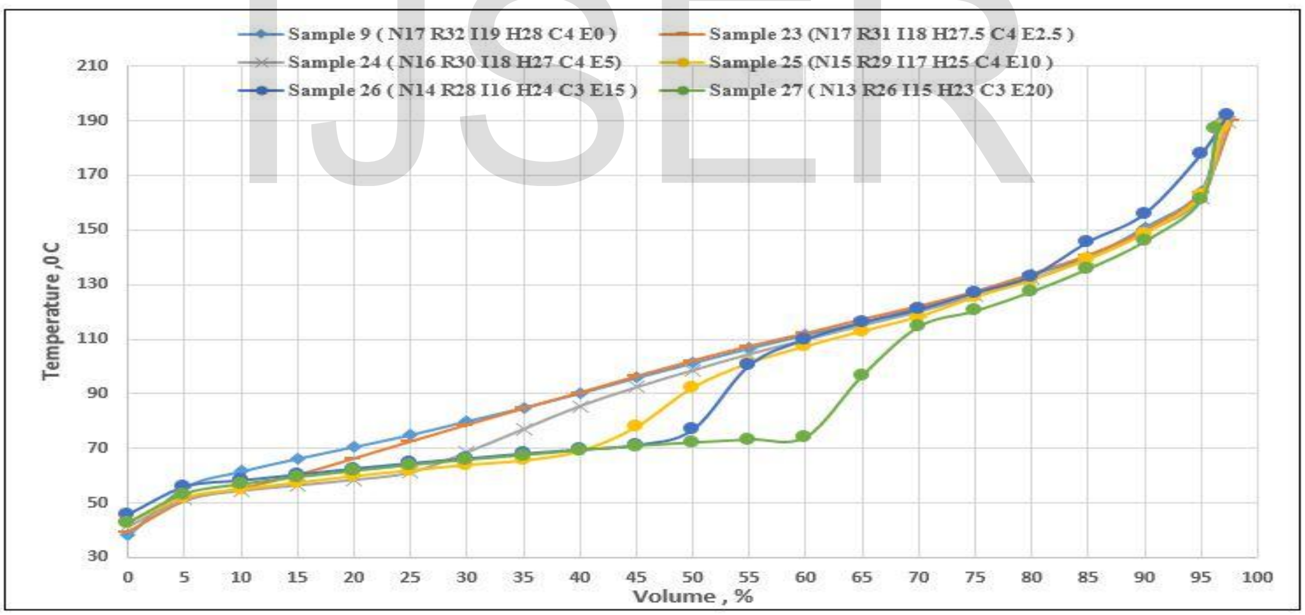

Fig. 12 ASTM Distillation Curve for Gasoline - Ethanol Blend Samples

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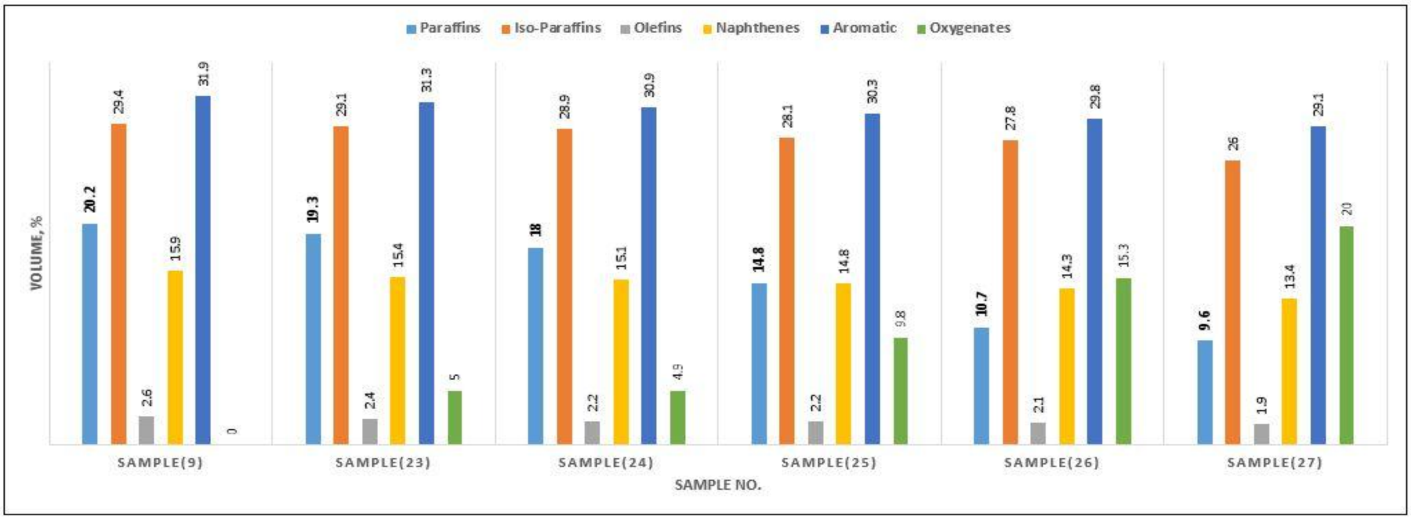

Fig. 13 Composition Analysis for Gasoline -Ethanol Blend Samples by Gas Chromatography

TABLE 4 Physico-chemical Characteristics of Gasoline -Ethanol Blend Samples.

Test	Method	Units	Ethanol Volume						EURO-6
			Sample 9	Sample23	Sample 24	Sample25	Sample 26	Sample 27	
Composition			$N_{17}R_{32}$ $I_{19}H_{28}C_4$ E_0	$N_{17}R_{31}$ $I_{18}H_{27.5}C_4$ $E_{2.5}$	$N_{16}R_{30}$ $I_{18}H_{27}C_4$ E_5	$N_{15}R_{29}$ $I_{17}H_{25}C_4$ E_{10}	$N_{14}R_{28}I_{16}$ $H_{24}C_3$ E_{15}	$N_{13}R_{26}$ $I_{15}H_{23}C_3$ E_{20}	
Density at 15 °C	ASTM D4052	Kg/m^3	740.2	742.6	744.3	745.4	750	752.5	720-775
Reid Vapor Pressure	ASTM D5191	kPa	44	57	58	58	55	53	45-60
RON	ASTM D2699		85.9	95	98	103	102	97	Min.95
MON	ASTM D2700		78.7	86.1	96	98	96	93.6	Min.85
PON	(R+M)/2		82.3	90.55	97	100.5	99	95.3	
Distillation at 100 °C	ASTM D86	Vol. %	49	48.5	50.7	54.8	54.9	66	46-71
at 150 °C		Vol. %	89	88.9	89	90.4	87.6	91.2	Min.75
at FBP		°C	190.4	190.2	190.1	188.1	191.8	187	Max.210
Distillation Residue		Vol. %	1.2	1.2	1.2	1.2	1.3	1.2	Max. 2
Composition	ASTM D6729								-
Paraffins		Vol. %	20.20	19.3	18	14.8	10.7	9.6	-
Iso- Paraffins		Vol. %	29.40	29.1	28.9	28.1	27.8	26	-
Olefins		Vol. %	2.60	2.4	2.2	2.2	2.1	1.9	Max.18
Naphthenes		Vol. %	15.90	15.4	15.1	14.8	14.3	13.4	-
Aromatics		Vol. %	31.90	31.3	30.9	30.3	29.8	29.1	Max. 35
oxygenates		Vol. %	0.0	2.5	4.9	9.8	15.3	20	-
Benzene		Vol. %	0.61	0.6	0.6	0.6	0.59	0.58	≤1
Toluene		Vol. %	7.6	7.5	7.4	7.2	6.9	6.5	-
Ethyl benzene		Vol. %	1.5	1.5	1.5	1.5	1.4	1.3	-
m-Xylene		Vol. %	3.5	3.5	3.5	3.4	3.2	3.0	-
p-Xylene		Vol. %	1.4	1.4	1.4	1.4	1.3	1.2	-
o-Xylene		Vol. %	1.9	1.9	1.9	1.8	1.8	1.7	-

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4 CONCLUSIONS

The following conclusions could be drawn from this study:

- Ethanol-gasoline-blends can be used as an alternative fuel for variable speed spark ignition up to 5 vol. % blends without engine modification.
- Gasoline A 98 and A 95 are produced by adding oxygenated compound (ethanol) to the optimum sample to achieve a satisfactory blends corresponding with all specification of Euro-6 regulations. The new blends are friendly environmental and contain the less amount of benzene content.
- E2.5 (sample 23) and E5 (sample 24) are the optimum selected percentages which give the best results in comparisons with others according to standard European regulations (Euro-6).
- The composition of sample 23 (E2.5) is 17 vol. % straight run naphtha, 31 vol. % reformate, 18 vol. % isomerate, 27.5 vol. % hydrocracked naphtha, 4 vol. % Coker naphtha and 2.5 vol. % ethanol. In addition, the composition of sample 24 (E5) is 16 vol. % straight run naphtha, 30 vol. % reformate, 18 vol. % isomerate, 27 vol. % hydrocracked naphtha, 4 vol. % Coker naphtha and 5 vol. % ethanol.
- In the sample (23) , the density at 15 ^{o}C, RVP, RON, MON, PON, aromatics and benzene contents are 740.2 kg/m^3, 57 kPa, 95, 86.1, 90.55, 31.3 vol. % and 0.6 vol. % respectively. In sample(24), the density at 15 ^{o}C, RVP, RON, MON, PON, aromatics and benzene contents are 742.6 kg/m^3, 58 kPa, 98, 96, 97, 30.9 vol. % and 0.6 vol. % respectively.
- Maximize the quality and quantity of environmental gasoline according to standard European regulations (Euro-6).
- 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.

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