ISSN:1306-3111
e-Journal of New World Sciences Academy
2006, Volume: 1, Number: 4
Article Number: A0012

NATURAL AND APPLIED SCIENCES
ENGLISH (Abstract: TURKISH)
NWSA Received: June 2006
NWSA Accepted: October 2006

Hasan Bayındır
Dicle University
Faculty of Technical Education
Department of Machine Education
Batman-Türkiye

EFFECT OF ETHANOL-GASOLINE BLENDS ON EXHAUST EMISSION IN A SI ENGINE; ETHANOL POTANTIAL IN GAP

ABSTRACT

In this study, the effect of using unleaded gasoline and unleaded gasoline-ethanol blends on exhaust emissions was experimentally investigated. Research was carried out to find the effect of ethanol-gasoline blends on exhaust emissions. In experiments, firstly the effect of gasoline on exhaust emissions at 1/4, 1/2 and widest throttle opening position was tested. Secondly, tests carried out with blends which were prepared with 15%, 25%, and 35% ethanol added gasoline at volumetric rates. The experiments were conducted on a four stroke, one cylinder, air cooled Spark Ignition (SI) engine. In comparison to gasoline, ethanol-gasoline blends gave cleaner CO and HC emissions. As there is wide and well-watered agricultural area in GAP (Southeastern Anatolia Development Project) region, a great many plants of which ethanol can be produced will be cultivated.

Keywords: Ethanol, Gasoline, Alternative Fuels, Exhaust Emissions.

BUJİ İLE ATEŞLEMELİ BİR MOTORDA ETANOL-BENZİN KARIŞIMLARININ EGZOZ EMİSYONU ÜZERİNE ETKİLERİ; GAP'IN ETANOL POTANSİYELİ

ÖZET

Bu çalışmada, şeker pancarından üretilmiş olan etanol benzine değişik oranlarda katılarak test edilmiştir. Çalışmalar etanol-benzin karışımlarının egzoz emisyonu üzerindeki etkilerini bulmak amacıyla sürdürülmüştür. Deneylerde, öncelikle benzinin 1/4, 1/2 ve 1/1 kelebek açıklığı durumlarında egzoz emisyonuna etkileri test edilmiştir. Daha sonra benzine hacimsel olarak %15, %25 ve %35 oranında etanol katılarak test edilmiştir. Deneylerde tek silindirli, 4 zamanlı ve hava soğutmalı buji ile ateşlemeli bir motor kullanılmıştır. Benzinle karşılaştırıldığında etanol-benzin karışımları daha temiz CO (Karbon monoksit) ve HC (Hidrokarbon) emisyonu vermiştir. Ayrıca, etanol bitkilerinin Güneydoğu Anadolu Bölgesinde yetiştirilebilir olması ve geniş sulanabilir arazilerin bulunması etanol üretimi için uygun ortam sağlamaktadır.

Anahtar Kelimeler: Etanol, Benzin, Alternatif Yakıt, Egzoz Emisyonu.

1. INTRODUCTION (GİRİŞ)

Not only does using ethanol help reduce Turkish and European dependence on foreign oil, but, because ethanol is produced from crops grown in the Turkey, it can also help stabilize commodity prices. In the near future, wind energy, hydro-electrical power plants as well as biomass, bio-methanol, bio-diesel especially bio-ethanol will have great importance as fuel [1].

Sustaining a clean environment has become an important issue in an industrialized society. The air pollution caused by automobiles and motorcycles is one of the most important environmental problems that have to be tackled. Exhaust emissions aroused from engines depend on fuels composition. Since using ethanol–gasoline blended fuels can ease off the air pollution and the depletion of petroleum fuels simultaneously, many researchers have been devoted to studying the effect of these alternative fuels on the performance and pollutant emission [2 and 3]. For an engine, alcohols are likely alternative automotive fuels in that they have properties which would allow its use in present engines with minor modifications. Alcohol has a higher octane number than gasoline [4].

Ethanol could reduce the CO and unburned Hydrocarbon (HC) emissions to some amount. The reduction of CO emission is apparently caused by the wide flammability and oxygenated characteristic of ethanol [5].

Ethanol is commonly produced by fermenting any biomass high in carbohydrates, like corn or wheat, through a process similar to brewing beer. Ethanol can also be produced from urban waste, agricultural and forestry residues, and from certain energy crops. Major scientific efforts are underway to develop cost-effective technologies in this area. Since ethanol can be fermented and distilled from biomass it can be considered as a renewable energy [6].

Some studies showed that using ethanol–gasoline blends in an engine would increase the emission of formaldehyde, acetaldehyde and acetone. Although the emission of aldehyde will increase when ethanol is used as a fuel, the damage to the environment by the emitted aldehyde is far less than that by the poly nuclear aromatics emitted from burning gasoline [7 and 8]. It is also indicated that different air–fuel ratios would clearly change CO emission. Using ethanol–gasoline fuel would produce less CO and NO_x than using gasoline, especially in rich conditions [9]. It is experimented that using ethanol-gasoline blends in SI engines can reduce CO, HC and NO_x emissions [10].

When the fuel contains oxygen (e.g., with alcohols), the procedure for determining the overall combustion equation is the same except that fuel oxygen is included in the oxygen balance between reactant and products [11].

For ethanol, C_2H_5OH, the stoichiometric combustion equation is;

$$C_2H_5OH + 3(O_2 + 3.773N_2) = 2CO_2 + 3H_2O + 11.32N_2$$

$$\text{And } A/F)_S = 9.00 \quad (1)$$

Some scientist recently had tested 10%, 20%, 30% and 40% ethanol of blended fuels in variable compression ratios of engine. They found that the increase of ethanol content increases the octane number, but decreases the heating value. The 10% 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% ethanol with 90% gasoline [14]. Since ethanol can be obtained from renewable energy sources, it became more and more important. This entire expectations drive scientist to research on renewable energy.

2. THE IMPORTANCE OF ETHANOL FOR GAP REGION (ETANOLUN GAP İÇİN ÖNEMİ)

Environmental policies and programs can have a significant impact on the development of alternative fuels. Issues are; production, water, natural gas requirements, odors and waste. Issues such as poor local air quality and health impacts caused by high levels of air contaminants are driving significant changes in fuel composition throughout Europe. Emerging issues such as climate change and the ratification of the Kyoto Protocol are likely to have the same kind of impact on alternative fuels and fuel composition that local air quality issues have had in the past. With the respect to E.U. Adaptation Criterions vehicles in Turkey should use at least 2% ethanol blended gasoline. In every year, approximately 40 million ton fuel is used by vehicles in Turkey. Consequently Turkey obliged to produce at least 800,000 ton ethanol yearly. From the point of view to its scopes, purposes and with its extent Southeastern Anatolia Project is one of the most wide development projects in the world. It covers approximately %10 Turkey’s area. In advance, GAP was planned to develop southeastern of Turkey. However in 1989 when GAP master plan was prepared, the project was turned to be a multi-sectoral integrated regional development project. In this way, GAP regional Development Project aims to prepare programs to eliminate poverty from southeastern Turkey, to make more employments and to protect environment. In the region, new species of plant will be cultivated and harvested at least two times in a year. In GAP region raising different kinds of plants is rapidly increasing. However main crop in region are wheat and broad bean. Plants, which will be raised in GAP region, will positively assist country’s economy so that authorities must pay attention to this reality.

There is no sugar production factory in this region and sugar production factories in other parts of Turkey are far from GAP region. In this case transportation costs and expenditures are so high that production and processing of sugar beet is not profitable at present. If there are sugar factories and facilities sugar beet will give a great support to the country’s economy. In the future petroleum fuels will entirely be used up. Thus, ethanol will be used as fuel in an internal combustion engine. Different kind of species which are expected to be raised in GAP region is shown in Table 1.

If Table 1 and Table 2 are carefully viewed, the effect of raising new species of plants on country’s economy and agricultural marketing can be seen. Well-watered area in GAP region is shown on Table 2. Technical specifications of ethanol, methanol and gasoline can be viewed in Table 3.

The use of ethanol-gasoline blends as a fuel is an important alternative strategy for gradually replacing hydrocarbon fuels for a renewable source in a view of a future expected petroleum depletion. Many researches have carried out studies on the effects of ethanol-gasoline blends on the performance as well as on pollutant emission problems of engines. In some countries, ethanol as fuel is not economical with respect to gasoline, and must be supported by subsidies [17 and 18].

To overcome the land problems and develop price-competitive ethanol, new technologies for producing ethanol from cellulose are required [19 and 20].

Table 1. Plants expected to be raised in GAP region [13]
(Tablo 1. GAP bölgesinde yetiştirilebilen bitkiler [13])

	Cultivation Rate (%)	Area (Hectares)	Efficiency (kg/ha)	Total Production (Ton)
Cotton	31.18	434.556	34.512	1.499.729
Grain	29.25	407.831	3.848	1.569.427
Corn	0.9	12.549	3.509	44.033
Rice	1.98	27.533	4.656	128.189
Lentil-chickpea	1.74	24.213	2.162	52.355
Beans	2.22	30.889	2.052	63.399
Tobacco	1.13	15.763	1.588	25.045
Tuber Plant(potato)	5.86	81.614	46.989	3.834.940
Linen	0.51	7.066	900	6.350
Soybean	0.06	817	2.000	1.634
Sesame-sunflower	2.00	27.817	2.255	62.728
Watermelons	7.42	103.361	28.755	2.972.146
Bait Plants	5.89	82.096	12.000	985.152
Bait's seed	0.46	6.371	700	4.460
Fruit	2.40	33.550	15.483	519.460
Pistachio	0.68	9.472	1.038	9.832
Oliver	0.38	5.361	2.160	11.580
By-product Sesame	4.77	66.497	2.250	148.008
By-product Corn	2.25	31.398	2.330	73.167
By-product Vegetables	0.62	8.647	28.671	47.920
By-product Peanut	2.20	30.733	2.564	78.805
By-product Soybean	2.79	38.934	1.630	63.465

Table 2. Well-watered areas in GAP region [14 and 15]
(Tablo 2. GAP bölgesinde sulanabilir araziler [14 and 15])

Province	Well-Watered Areas		Before GAP		With GAP		Non-Watered	
	Hectares	%	Hectares	%	Hectares	%	Hectares	%
Adıyaman	198.873	7.4	16.818	14.8	74.410	4.4	107.645	11.8
Diyarbakır	540.549	20.0	21.600	19.0	365.258	21.8	153.736	16.9
Gaziantep	357.146	13.2	17.736	15.3	171.700	10.3	168.070	18.5
Mardin	435.429	16.1	12.376	10.9	107.750	6.4	315.303	34.7
Siirt+Batman	141.239	5.30	6.717	5.9	82.450	4.9	52.036	5.7
Şanlıurfa	1.025.956	38.0	38.735	34.1	874.600	52.2	112.621	12.4
TOTAL	2.699.237	100.0	113.622	100.0	1.676.204	100.0	909.411	100.0

Table 3. Technical specifications of ethanol, methanol and gasoline [16]
(Tablo 3. Etanol, metanol ve benzinin teknik özellikleri [16])

	Gasoline (izo-octane)	Methanol	Ethanol
Chemical formula	C_8H_{18}	CH_3OH	C_2H_5OH
Molecule mass	114.2	32.04	46.07
C/H mass rate	5.3	3.0	4.0
%H mass	15.9	12.6	13.1
%C mass	84.1	37.5	52.1
%O mass	0.0	49.9	34.8
Freezing point, °C, 0.1 MPa	-56.5	-97.	-17.8
Boiling point , °C, 0.1 MPa	125	65	78.5
Density, kg/m^3	702	796	794
Specific latent heat of vaporization, J/g	302.4	1167	921.1
Lower heating value, MJ/kg	44.2	20.0	27.0
Lower heating value, MJ/lt	31.0	15.9	21.4
Air-fuel ratio	15	6.44	8.96
Ignition limits(volumetric)%	1-6	7-36	4.3-18
Steam pressure, 38°C, kPa	80	32	21
Research Octane Number (RON)	100	110	108
Motor Octane Number (MON)	100	94	94

3. EXPERIMENTAL STUDY (DENEYSEL ÇALIŞMA)

Experiments were conducted on a four stroke, one cylinder, air-cooled compression ratio of 8:1, total swept volume 392 cm^3, SI engine. The engine was coupled to an electrical dynamometer.

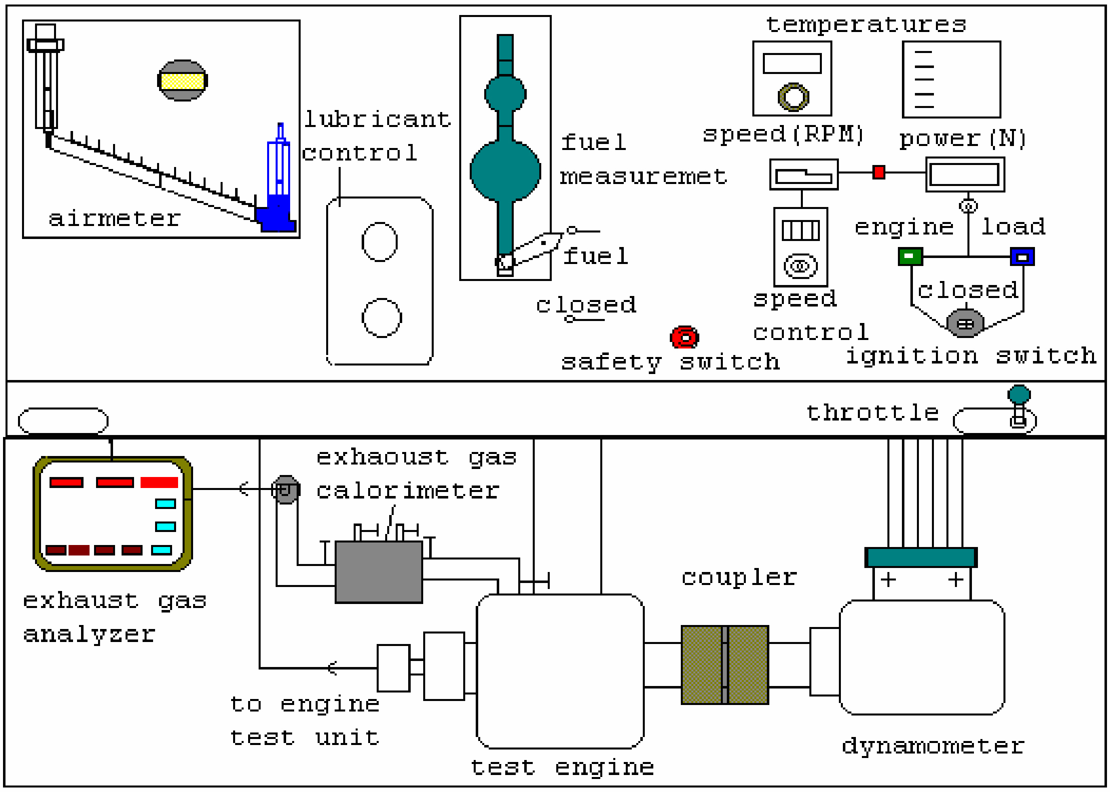

Figure 1. Schematic diagram of experimental setup
(Şekil 1. Deney tesisatının şematik görünümü)

Experiments started with unleaded-gasoline (E0) at 1:4, 1:2, and 1:1 throttle opening position respectively at various engine speeds with loaded engine. The required engine load was obtained through dynamometer control.

Before running the engine to a new fuel blend, it was allowed to run for sufficient time to consume the remaining fuel from the previous experiment. After that, experiments were maintained with 15% (E15), 25% (E25) and 35% (E35) ethanol-gasoline blends respectively.

Density of ethanol which is added to gasoline was 794 kg/m^3, lower heating value 27 mj/kg, stoichiometric air-fuel ratio was 9:1 and octane number of fuel was 108. In order to prevent decomposing of ethanol-gasoline blends a mixer was mounted in oil tank and during the experiment blend was mixed. Heat of oil in the crankcase of the engine was 75 $\pm 2^oC$ and the engine speed deviation was ±10 Revolution Per Minute (RPM).

4. FINDING AND RESULTS (BULGULAR VE SONUÇLAR)

4.1. The Effects of Ethanol-Gasoline Blends on the Performance of Engine (Etanol Benzin Karışımının Motor Performansı Üzerine Etkisi)

Because of the lower heating value of ethanol compared to gasoline heating value, ethanol can produce less mechanical energy by converting heat energy. Because of that restriction a decrease in the engine torque and power output measurement was observed. Owing to the higher octane number of ethanol-gasoline blends than unleaded gasoline, the compression ratio of engine was increased from 6 to 8.

As results using 20% ethanol-80% gasoline fuel mixtures in engine, power output increased 2.22 percent and consequently specific fuel consumption was decreased [21]. Maximum brake thermal efficiency was experimented when 25% ethanol–75% gasoline was used in the blend for all engine speeds with compression ratio of 9:1.

4.2. The Effects of Ethanol-Gasoline Blends on Exhaust Emissions (Etanol Benzin Karışımının Egzoz Emisyonları Üzerine Etkisi)

Emission tests were conducted on a Exhaust Gasses Emission Analyzer equipment. Experimental results indicated that the CO and HC emissions decreased drastically as a result of the leaning effect caused by ethanol addition. It was also indicated that the more ethanol added to blend the less HC and CO concentrations emitted. It can be inferred from the experimental results if ethanol is used in an internal combustion engine the environment can be kept cleaner. Furthermore when ethanol added in gasoline, octane number of gasoline will increase, so lead-tetraethyl will no longer be added in gasoline that the poisonous effect of this kind of additions will be avoided.

The concentration of CO emission decreased when relative air/fuel ratio (λ) increased to 1. CO emissions were observed variously as it is a function of λ. This indicates that the engines operated in leaner conditions, closer to stoichiometric burning, as the ethanol content was increased. Combustion process for the blend was closer to stoichiometric burning; therefore the concentrations of CO emissions were decreased.

$$\lambda = (A/F)_{actual} \; / \; (A/F)_{stoichiometric} \quad (2)$$

$$\varepsilon = \text{max. cylinder volume/min. cylinder volume}$$

$$\varepsilon = (V_d+V_c) \; / \; V_c$$

where V_d is the displaced volume and V_c is the clearance volume.

Engine power, torque and exhaust emissions were varied in connection with throttle opening position. When throttle valve gap became wider, engine power, maximum torque and CO emissions increased considerably. Figure 2. and Figure 3. shows the increase on CO and HC emissions and correlation with throttle opening position in a loaded engine. When throttle opening is narrowed, CO and UHC emissions decreased.

When throttle valve was at 1:4 opening position, with using E0, CO emissions decreased by 44.54%, and by using E15, emissions decreased by 38.75%. Decrease of CO emissions was recorded by 33.33% when E25 was used and by 31.05% when E35 was used. It is also observed that when E35 was used as a fuel in a full loaded engine CO emissions were decreased by 33.63%.

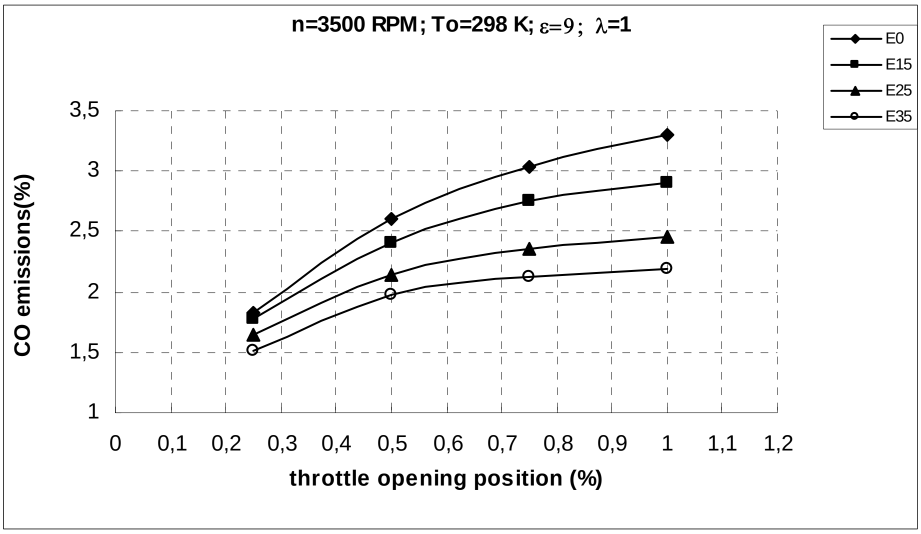

Figure 2. CO emissions by using ethanol-gasoline blends at different throttle opening positions
(Şekil 2. Gaz kelebeğinin farklı pozisyonlarında etanol-benzin karışımlarından kaynaklanan CO emisyonlarının benzine göre değişimi)

As it is illustrated with pertaining Figures, CO and unburned HC emissions varied when λ changed. However, CO emissions were more effected by various λ values then that of unburned HC emissions.

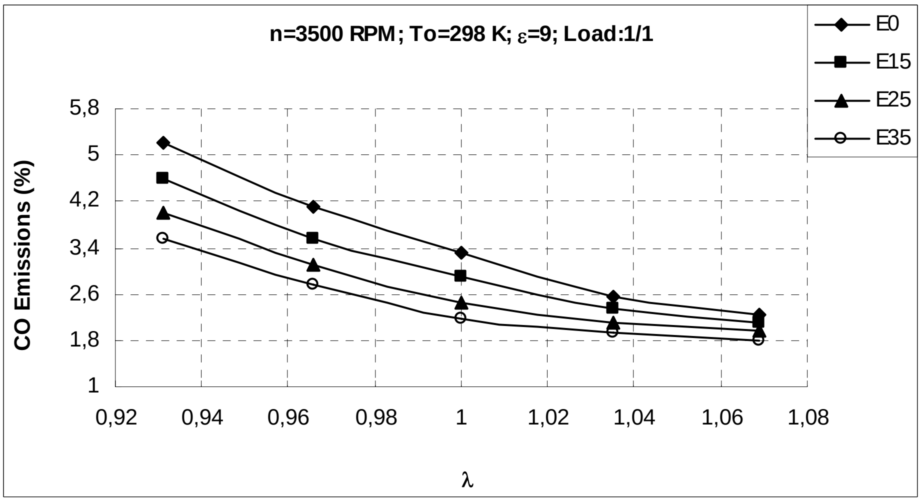

Figure 3. Correlation between λ and concentration of CO emission in an ethanol-gasoline blend fueled engine
(Şekil 3. λ'nın değişik durumlarında etanol-benzin karışımlarından kaynaklanan CO emisyonlarının benzine göre değişimi)

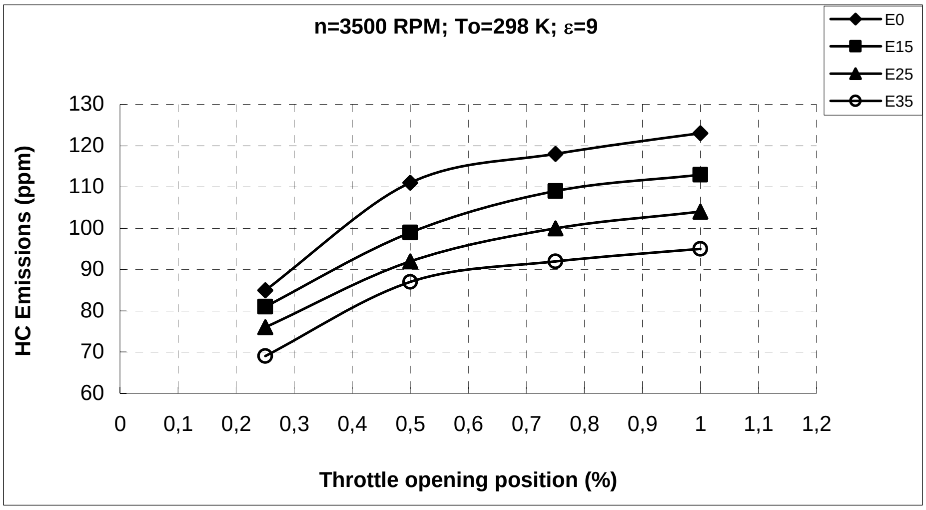

Figure 4. Correlations between throttle opening positions and concentrations of unburned HC emissions on an ethanol-gasoline blend fueled engine
(Şekil 4. Gaz kelebeğinin farklı pozisyonlarında etanol-benzin karışımlarından kaynaklanan HC emisyonlarının benzine göre değişimi)

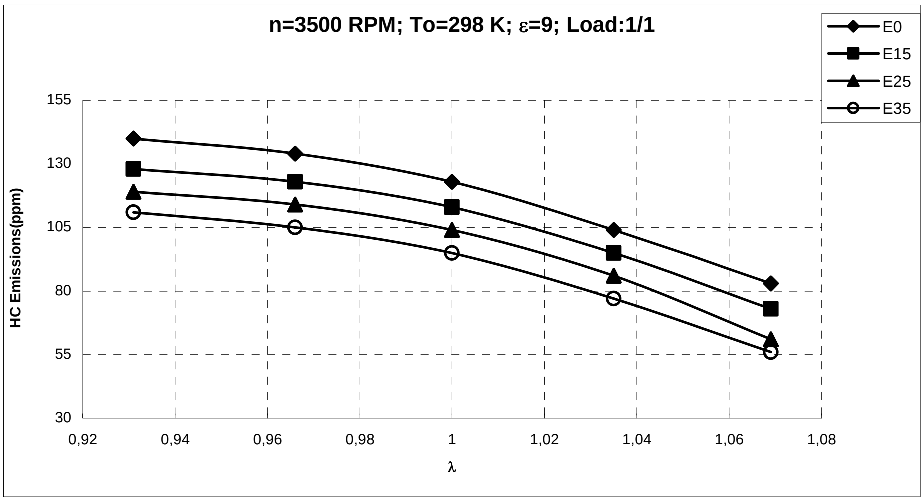

Figure 5. Correlations between relative air-fuel ratio and concentrations of HC emissions on an ethanol-gasoline blend fuelled engine
(Şekil 5. λ'nın değişik durumlarında etanol-benzin karışımlarından kaynaklanan HC emisyonlarının benzine göre değişimi)

5. CONCLUSIONS (SONUÇ)

Efforts for regional rural development consume information, but generate a considerable amount of surplus information as well. Thus, another dimension of researching in regional development is to make this surplus information usable and marketable.

The main aims of GAP is to develop improved varieties, introduces varieties of major crops like wheat, food legume, barley, sugar beet, cotton, soybean, sunflower, maize, olives, pistachios, and other specialty products. It is clear that there is a potential, of production ethanol and other kind of alternative fuel in GAP region. Production and utilization of ethanol in GAP region will have great positive effect on country's economy and market. In GAP region raising plants which are source of renewable and sustainable energy will make positive effect on country's economy and employment.

In this study, engine performance and pollutant emissions were measured by using the ethanol–gasoline-blended fuel under different relative air–fuel ratios and at different throttle opening positions. The results indicated that the relative air–fuel ratio and ethanol content play an important role in combustion process. The results also indicated that the presence of ethanol compounds in gasoline fuels significantly influence exhaust emissions and engine performance.

As the engine which was used in experiments designed and produced with the respect to gasoline use, the engine performance was observed better in gasoline use. However, when ignition timing, air-fuel ratio, and compression ratio were increased and when intake charge was preheated all ethanol-gasoline blends (E15, E25, and E35) gave better engine performance compared to gasoline use.

Engine performance was observed best when E25 was used in all throttle opening positions.

Experimental results indicated that using ethanol–gasoline blends, the torque output slightly decrease and fuel consumption of the engine slightly increased.

CO emissions depend on relative air–fuel ratio. With the increase of ethanol content, CO emissions were decreased due to oxygen enrichment coming from ethanol.

Unburned HC emissions are the result of incomplete combustion. It is related to relative air–fuel ratios. When λ was slightly larger than 1, HC emissions were the lowest. When λ was far from 1, HC emissions increased again. It was noted that ethanol-gasoline blends could reduce HC emissions because of oxygen abundant.

NOMENCLATURE (BİLİMSEL ADLANDIRMA)

λ : Relative air/fuel ratio
n : Engine speed, revolutions per minute(RPM)
T_0 : Initial atmospheric temperature (Kelvin)
ε : Compression ratio
V_d : Displaced volume (cm^3)
V_c : Clearance volume (cm^3)
$A/F)_s$: Stoichiometric air/fuel ratio
$A/F)_a$: Actual air/fuel ratio
UHC : Unburned hydrocarbon emissions
C_2H_5OH : Ethanol (ethyl alcohol)
GAP : Southeastern Anatolia Development Project
E25 : 25% ethanol blended gasoline
RPM : Revolution per minute

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