Available online at www.academicpaper.org
Academic @ Paper
ISSN 2146-9067
International Journal of Automotive Engineering and Technologies
Vol. 5, Issue 3, pp. 125 – 135, 2016

International Journal of Automotive Engineering and Technologies
http://www.academicpaper.org/index.php/IJAET

Original Research Article

An Experimental and ANNs Study of the Effects of Safflower Oil Biodiesel on Engine Performance and Exhaust Emissions in a CI Engine

İlkerÖrs*[1], Veli Bakırcıoğlu[1]

Vocational School of Technical Sciences, Aksaray University, 68100, Aksaray, Turkey.

Received 18 November 2016 Accepted 19November 2016

Abstract

In this study, the effects of diesel fuel–biodiesel (produced from safflower oil) blends on engine performance and exhaust emissions were investigated as experimentally in a single cylinder, four-cycle, normal aspirated diesel engine. In the results of tests, engine torque, engine power and specific fuel consumption as performance values of test fuels were commentated. Values of engine torque and engine power from biodiesel were lower than diesel fuel fuel as average 26% amount, and values of specific fuel consumption from biodiesel were higher than diesel fuel as average 41.5% amount. CO emission values of biodiesel decreased as average 74% amount according to diesel fuel. With using biodiesel, increased as average 2.45 fold amount for CO_2 emissions, as average 1.3 fold amount for NO emissions, and decreased as average 87% amount for HC emissions with compared to diesel fuel. The obtained values were estimated for different inputs by using the ANNs model. The data obtained from the ANNs is very close to the experimental data.

Keywords: Safflower oil biodiesel, engine performance, exhaust emissions, diesel engine.

*Corresponding Author:

E-mail:ilkerors@hotmail.com

1. Introduction

Increased global warming and decline in petroleum reserves in the world have led to the need for alternative engine fuels. Nowadays, biodiesel is the most common alternative engine fuel for diesel engines (CI). The most important reasons to prefer of biodiesel are to be especially renewable and environmental friendly. Besides, it can use in CI engines as pure and mixing due to the properties of fuel and physico-chemical of biodiesel are similar with diesel fuel.

Biodiesel can produce from all vegetable oils and animal fats [1-4]. However, researchers have oriented to the production of biodiesel from waste cooking oil in recent years [5-8]. The most widely method in biodiesel production is transesterification that is the name of the chemical esterification process which is converts the molecules called triglyceride of the vegetable oil and animal fat similar to the molecular properties of diesel fuel to short straight chain and it is reduce density and viscosity by separating fatty acids from glycerol [9].

The following results were encountered when the literature survey on the use of biodiesel in CI engines is made:

Biodiesel has been no significant effect on engine performance in low proportions mixtures [10-12]. Besides, the addition of biodiesel up to 20% to diesel fuel has been shown to improve the lubrication properties of the fuel [13-14]. Other than these, biodiesel has adversely affected engine performance parameters. Because, its some fuel properties such as lower heating value (LHV), density, kinematic viscosity have caused injection pumping losses and reduced combustion efficiency [15-18]. Exhaust gas temperature increased with using biodiesel due to early starting of combustion by shortening ignition delay of biodiesel [4,19-20]. Biodiesel increased NO_X emission due to its higher exhaust gas temperature and oxygen content, while it decreased CO and HC emissions.

In this study, we were investigated parameters of performance and exhaust emission obtained with used of its blends with diesel fuel and biodiesel produced from safflower oil as test fuels in a single cylinder CI engine. Artificial neural networks (ANNs) model created with experimental results and all results were compered.

2. Experimental Apparatus and Test Procedure

The tests were performed on a single-cylinder, four stroke, water cooled, direct injection CI engine. The specifications of engine, gas analyzer and hydraulic dynamometer used in tests were given in Table 1.

Table 1. Specifications of test apparatus.

Test Engine		
Model		Antor 3LD510
Engine type		Four stroke Direct injection
Cylinder number		1
Total cylinder volume (cm^3)		510
Diameter x Stroke (mm x mm)		85 x 90
Compression rate		17.5:1
Max. engine speed (rpm)		3300
Max. engine torque (Nm)		32.8
Max. engine power (kW)		9
Injector pressure (bar)		190
Hydraulic dynamometer		
Mark – Model		Net fren-NF150
Range of speed (rpm)		0-6500
Range of torque (Nm)		0-450
Load cell for torque		
Mark – Model		CAS-SBA 200L
Range of weight (kg)		0-200
Load cell for fuel consumption		
Mark – Model		CAS - BCL-1L
Range of weight (kg)		0-3
Gas analyzer		
Emission	Range of measurement	Accuracy
CO (v/v)	0-18	±0.001
CO_2 (v/v)	0-10	±0.01
HC (ppm)	0-9999	±1
NO (ppm)	0-5000	±1

In this study, diesel fuel and safflower oil based biodiesel produced by transesterification method in the pilot plant at Selcuk University in Konya/Turkey were used as test fuels. The fuel properties of diesel fuel, biodiesel and their binary mixtures were given in Tables 2. The prepared test fuels are coded as SB10 (90% diesel fuel + 10% biodiesel), SB20 (80%

diesel fuel + 20% biodiesel), SB50 (50% diesel fuel + 50% biodiesel) and SB (%100 biodiesel).The phase separations of test fuels were checked for six weeks, and any phase separation was not observed for this times. Fuel properties determined analysis methods as EN ISO 121 (density), EN ISO 310 (viscosity), ASTM D 24 (LHV) and EN ISO 516 (cetane number).

Tests were performed in Automotive Laboratory of Aksaray University at Aksaray/Turkey.Tests were carried out by keeping the speed fixed on each 200 rpm engine speed between 1000 – 3000 engine speeds by changing dynamometer load while motor is on full throttle opening. Any modifications weren't made on the test engine during the experiments.The schematic diagram of the experimental setup is shown in Fig. 1.

Table 2. Some fuel properties of test fuels.

Property	Diesel fuel	SB	SB10	SB20	SB50
Density, at 15ºC (kg/m^3)	834.5	885.6	837	844.4	859.6
Viscosity, at 40°C (mm^2/s)	2.794	4.353	2.855	3.02	3.434
LHV (MJ/kg)	43.14	38.59	42.54	42.08	40.72
Cetane number	55.2	55.7	55.3	55.5	55.6

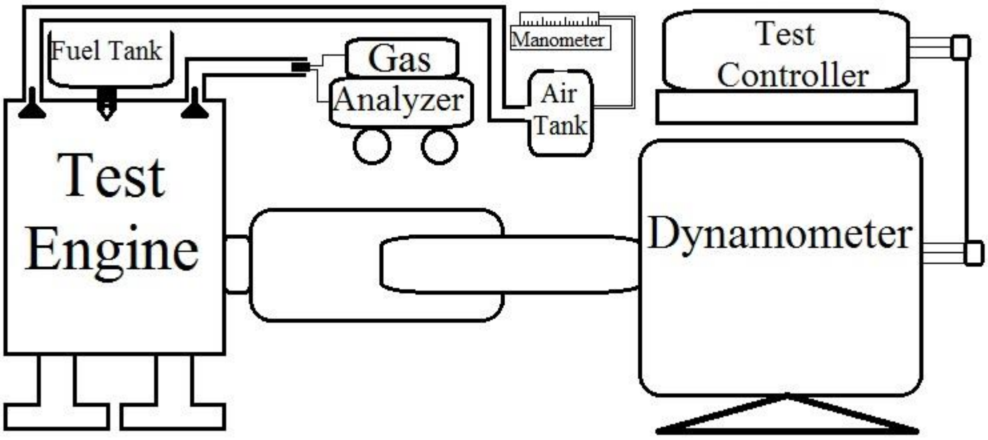

Fig. 1. The schematic diagram of the experimental setup.

An Artificial Neural Network model was constructed with the data obtained from the experimental study. In the modeling, 70% of the obtained data were used in ANNs training. The remaining 30% dataset was used in the validation and performance testing of the ANNs. A schematic representation of the ANNs is shown in Figure 2. In the ANNs model, which is trained as 2 inputs 9 outputs, the inputs are respectively the engine speed and fuel blends ratio. Outputs are engine performance and exhaust emission values.

The ANNs model was created using the Neural Net Fitting tool integrated with MATLAB software. It consists of two layers with forward feed.It also uses sigmoid function as an activation function in hidden layers.Weight coefficients were improved by Levenberg-Marquardt backpropagation algorithm and ANNs was trained.ANNs performance varies depending on some network characteristics such as the number of hidden layers, the number of network nodes in each layer.In this study, when the results obtained by trying different ANNs constructions are evaluated, the number of ANNs input layers which are given the best performance is selected as 10.

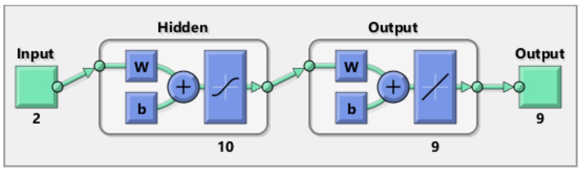

Fig. 2.ANNs model as schematic

3. Results and Discussions

Test results were presented as effective engine torque (EET), effective engine power (EEP), brake thermal efficiency (BTE), brake specific fuel consumption (BSFC) values and volumetric efficiency as motor performance parameters; carbon mono-oxide (CO), carbon di-oxide, nitrogen oxide (NO) and hydrocarbon (HC) as exhaust emission parameters.

3.1. Engine performance

EET is the torque values measured on the flywheel. The EET value of each fuel used in the tests is compared with that of the diesel fuel. Maximum EET value was obtained at 1400 rpm engine speed. EEP is the value calculated via the EET.Maximum EEP value was obtained at 2800 rpm engine speed. The effects of using biodiesel on engine torque and engine power are shown in Figure 3. The EET values obtained with SB10, SB20, SB50 and SB fuels were reduced by 5.47%, 11%, 14.11% and 26%, respectively, compared to diesel fuel. When the maximum EEP values are compared; at the engine speed of 2800 rpm, the EEP value obtained with diesel fuel was measured as 8.54 kW, while the EET value obtained with the SB10, SB20, SB50 and SB fuels was measured as 8.09 kW, 7.72 kW, 7.5 kW and 6.17 kW respectively. The primarily reason of decreased effect on EET and EEP of biodiesel is that it has lower LHV than diesel fuel. It is reported that low LHV decreases the combustion energy at the end of burn in the cylinder, so the EET and EEP values are reduced. However, increasing the viscosity of biodiesel has adversely affected the spray characteristics of the fuel.The diameter of sprayed fuel grains is higher than that of diesel fuel due to higher viscosity. Therefore, when the high viscosity fuels are injected, they is no good atomization, and cannot penetrate well into compressed air in the cylinder. In this case, the duration of evaporation of the fuel increases, and it burns for a longer period of expansion. These causes have been shown in many studies in the literature [1,3,17,21].

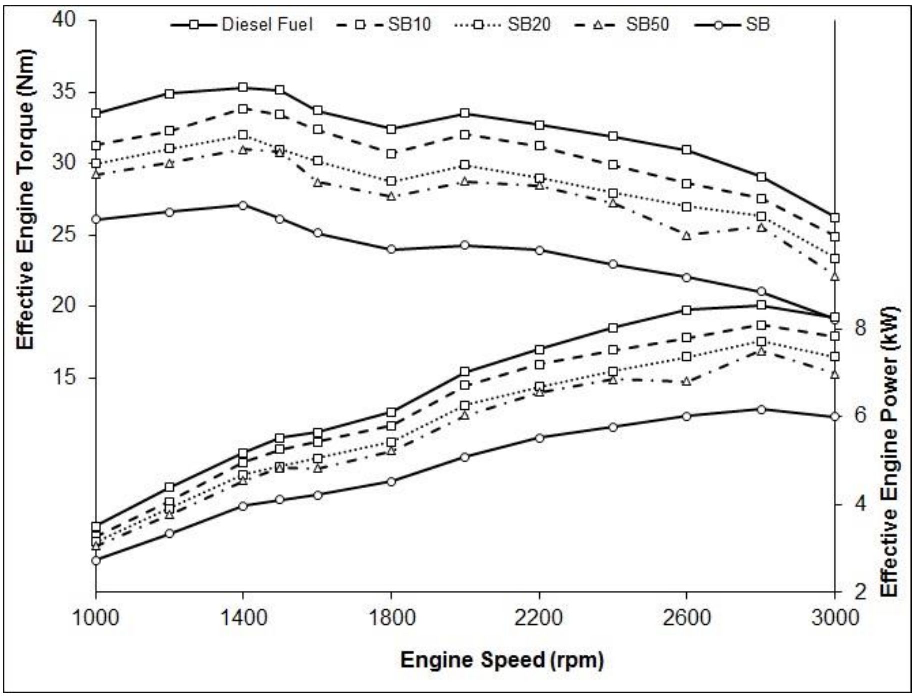

Fig. 3. Comparison of EET and EEP results

The BSFC is the amount of fuel consumed for obtain power per unit time. The lowest BSFC values are 264.71 g/kWh at 1500 rpm engine speed with diesel fuel, 285.52 g/kWh at 1400 rpm engine speed with SB10 fuel, 301.07 g/kWh at 1400 rpm engine speed with SB20 fuel, 314.72 g/kWh at 1400 rpm engine speed with SB50 fuel, 376.54 g/kWh at 1400 rpm engine speed with SB fuel. Thermal efficiency is the rate of conversion to useful work by engine of heat energy obtained with burning fuel. The BTE values obtained with SB10, SB20, SB50 and SB fuels were decreased by 4.33%, 9.56%, 11% and 21%, respectively, with respect to diesel fuel. Figure 4 shows the comparison of BSFC and BTE values obtained by test fuels. It is reported that the biodiesel usage adversely affects BSFC and BTE because of it reduces combustion quality and efficiency due to its lower LHV and bad spray characteristics [3-4,21-26].

Volumetric efficiency (VE) is one of the most important parameters used in commenting engine performance and emission parameters. Improved in performance and emission values seen thanks to burning closer to full combustion by the volumetric efficiency increases. Figure 5 shown changes in volumetric efficiency values. Maximum volumetric efficiency value was obtained at 1400 rpm engine speed. As the result of the use of biodiesel, the VE values obtained with SB10 fuel are 1.72% on average, the VE values obtained with B20 fuel are 3.69% on average, the VE values obtained with SB50 fuel are 5.4% on average and the VE values obtained with SB are 9.53% on average decreased in comparison with diesel fuel. Its waste exhaust gas temperature values are higher due to the burning-end temperature of biodiesel is higher than that of diesel fuel. Therefore, it is estimated that the VE values decreases for increased temperature of the air taken into the cylinder.

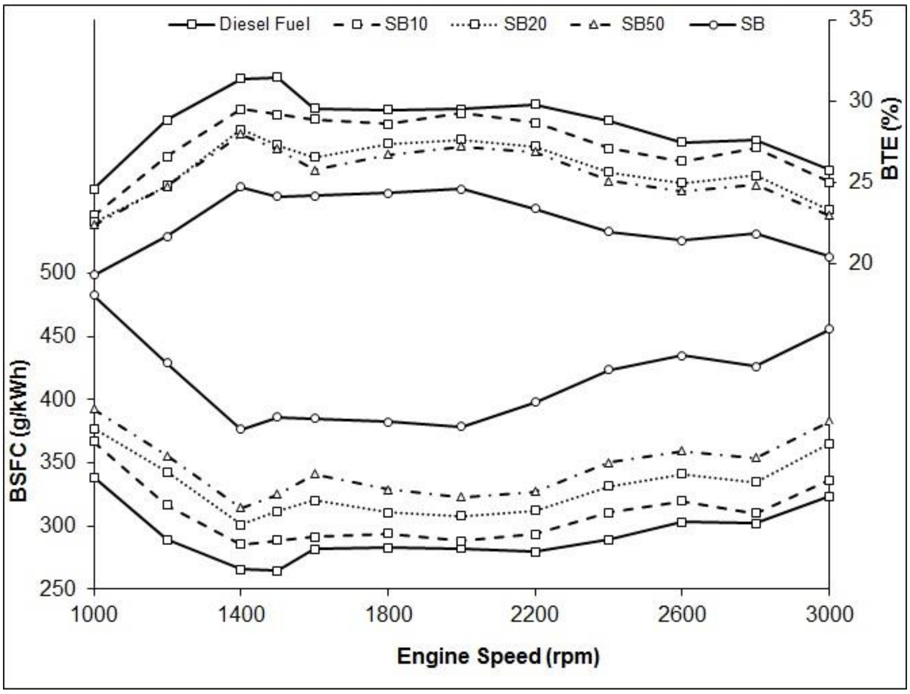

Fig. 4. Comparison of BSFC and BTE results

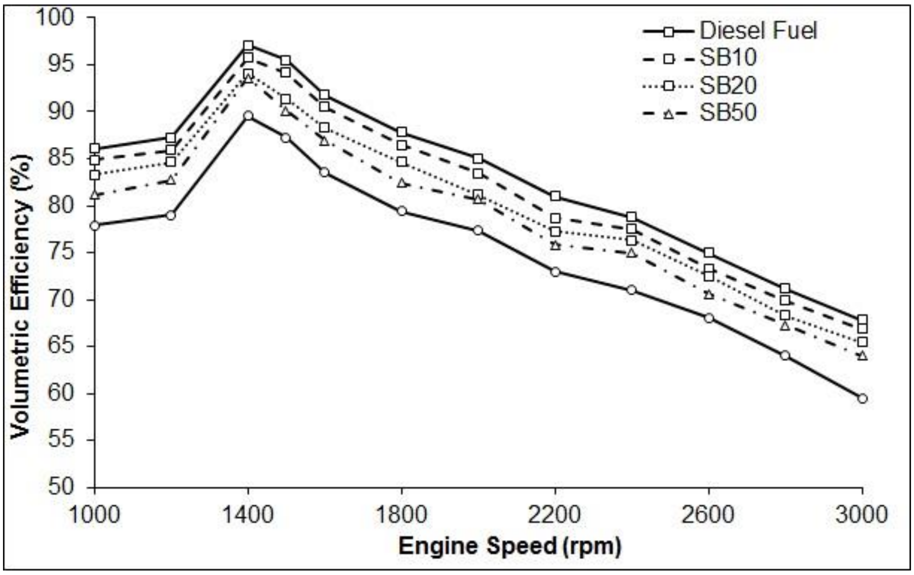

Fig. 5. Comparison of volumetric efficiency results

3.2. Exhaust emissions

The most important reason for the formation of CO emissions is the inadequacy of oxygen in the combustion chamber.It is seen that the use of biodiesel reduces CO emission values, and the CO emissions were further decreased due to increase in the proportion of biodiesel in the mixtures. The CO emission values decreased by 74.08% on average with use biodiesel. CO_2 emission, a sign of full combustion, is a gas that generated by combustion of hydrocarbons fuels and causes global warming by its greenhouse effect created in the atmosphere.However, some researchers think that CO_2 gas generated by the use of biodiesel is used by plants for photosynthesis [27-28]. The CO_2 emission values increased by 2.45 times on average with use biodiesel. Figure 6 shown changes in CO and CO_2 emissions. Many studies have shown that biodiesel decreased CO emission because of its oxygen content [1,3-4,18,23]. The increase in CO_2 emission values of biodiesel can be explained by the fact that the number of C atoms of biodiesel is higher than diesel fuel [15,21,25,29-30].

HC emission occurs due to causes such as not fully burning the fuel, reducing the combustion temperature and insufficient oxygen. Biodiesel decreased HC emission values by 86.65 % on average compare to diesel fuel. Reducing the HC emission values of biodiesel can be explained by the increase of the exhaust gas temperature due to improving the combustion efficiency of the oxygen content of biodiesel [1,3,18,23,31-32]. Figure 7 shown changes in HC and NO emissions. It is reported that the biodiesel usage increased the NO emissions because of its higher exhaust gas temperature and the oxygen content [3,33]. The NO emission values obtained with SB10, SB20, SB50 and SB fuels were increased by 15.67%, 31.29%, 94.55% and 1.3 times, respectively, with respect to diesel fuel.

3.3. ANNs modeling

After obtaining the model, output parameters were obtained with ANNs. The graphs showing the correctness of the output parameters obtained from ANNs are shown in Figure 8.When the engine performance parameters obtained by ANNs are examined, it is seen that the correlation coefficient of the EET data is 0.979, the correlation coefficient of the EEP data is 0.99, the correlation coefficient of the BSFC data is 0.988, the correlation coefficient of the BET data is 0.986 and the correlation coefficient of the VE data is 0.988. However, it is seen that the correlation coefficient values for exhaust emission parameters are 0.996 for CO_2 emission, 0.986 for CO emission, 0.993 for HC emission and 0.997 for NO emission.When these results are evaluated, ANNs model gives successful results in predicting of both engine performance parameters and exhaust emission parameters.

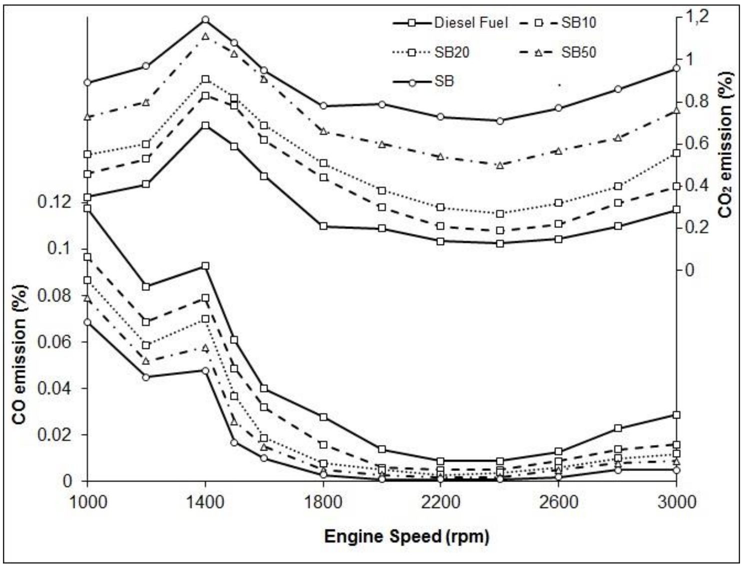

Fig. 6. Comparison of CO and CO_2 emissions results

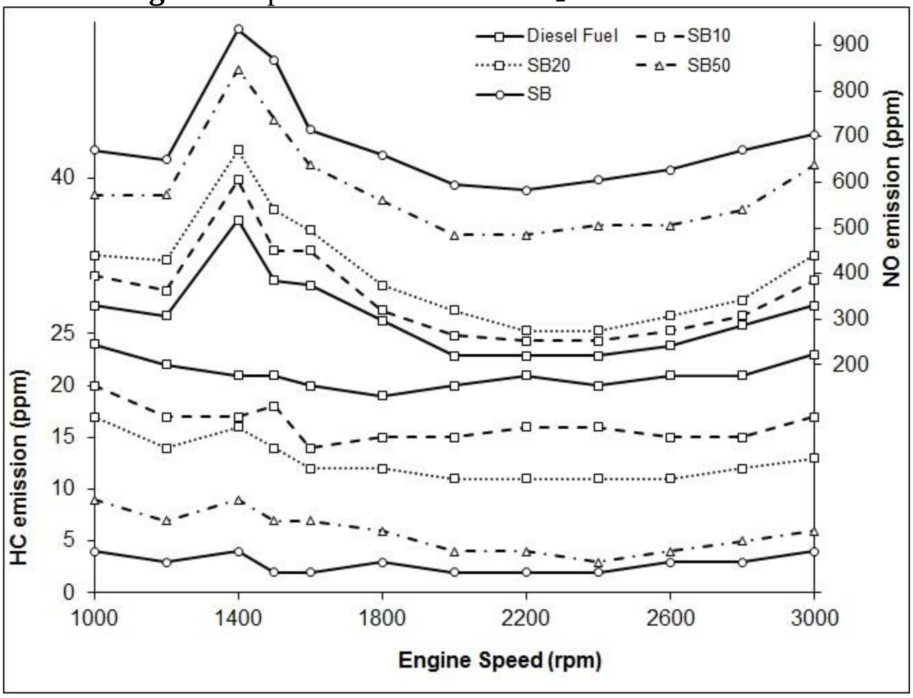

Fig. 7. Comparison of HC and NO emissions results

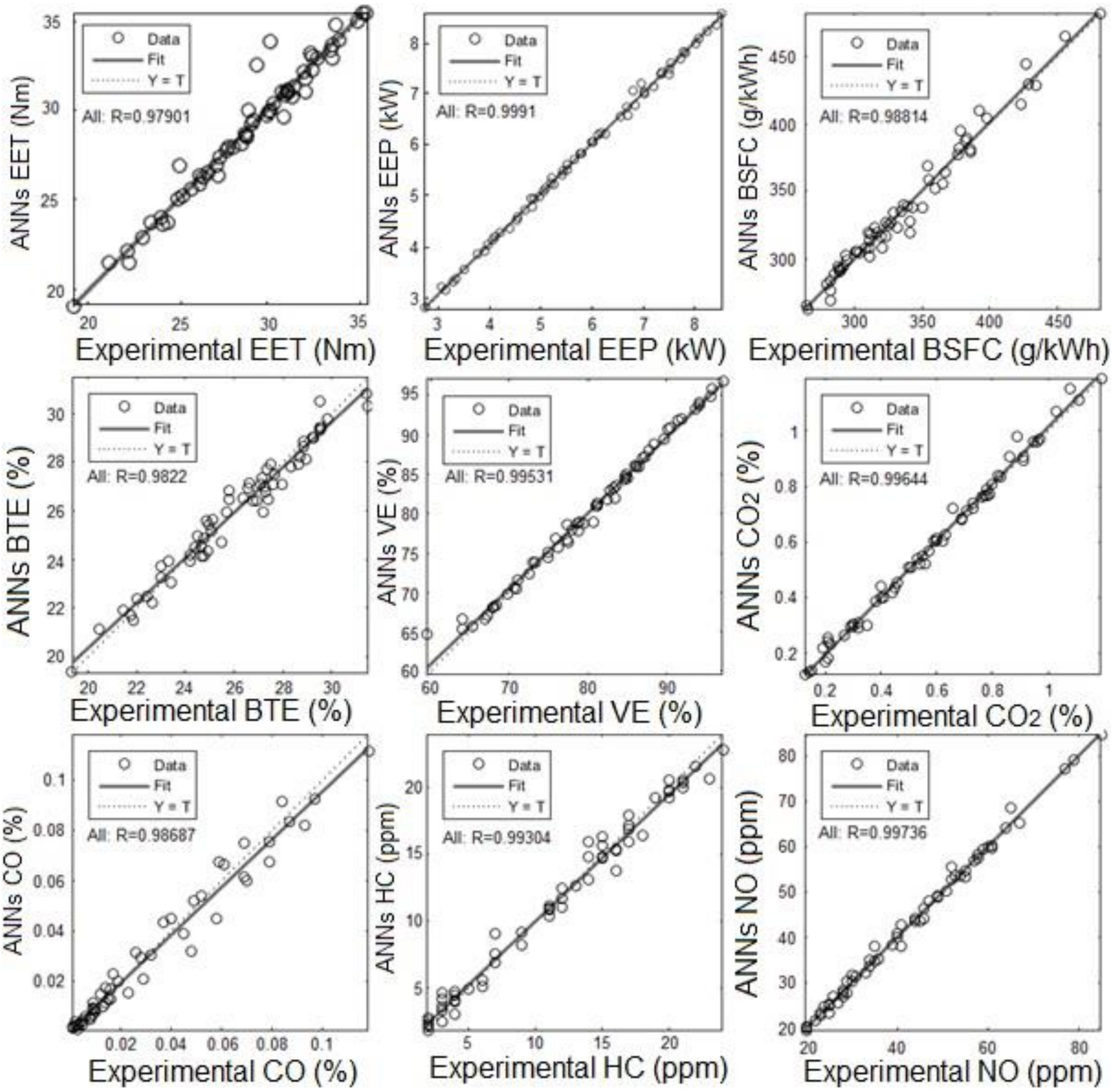

Fig 8. Correlation coefficients of ANNsprediction results

The comparison between the data obtained from ANNs and the experimental data is shown in Figure 9. As can be seen from the graph, the data obtained from the ANNs is very close to the experimental data.

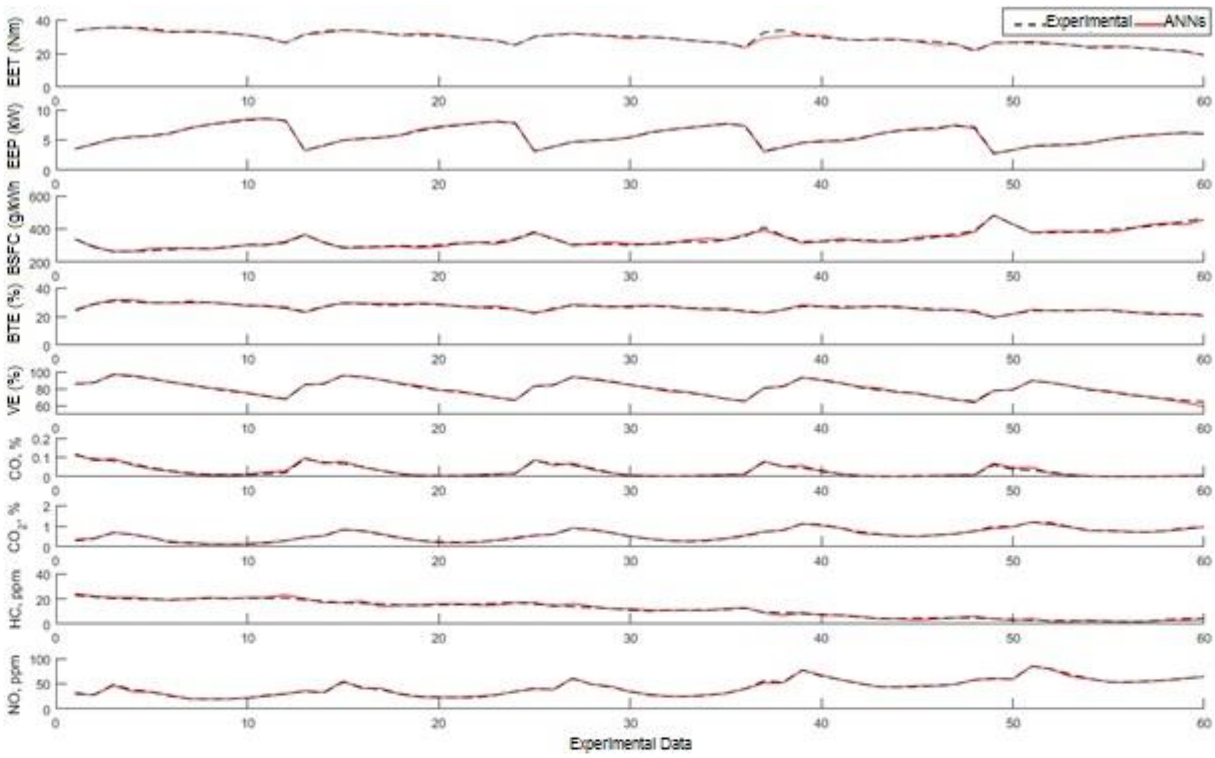

Fig 9. The comparison between the data obtained from ANNs and the experimental data.

4. Conclusion

As a result of the tests, the engine performance and exhaust emission values of biodiesel use were examined and the results are presented.The data obtained as a result of the tests were evaluated in general and the following results were obtained mainly;

- It has been found that the use of biodiesel improves the cetane number, but it adversely affect especially the fuel properties such as LHV, viscosity, density, CFPP, oxidation stability.
- The use of biodiesel caused some reduction in engine performance parameters.
- While the use of biodiesel decreased CO and HC emissions, it increased CO_2 and HC emissions.
- These output parameters can be estimated for different inputs by using the ANNs model.

These results; Although biodiesel reduces engine performance values somewhat compared to diesel fuel, the fact that the emission values are very favorably influenced suggests that biodiesel and biodiesel blended fuels can be used in diesel engines without any modification to the engine and without the need to change any operating parameters.

Acknowledgement

This study was supported by the grants from Scientific Research Projects Coordination Unit of Aksaray University (Project No: 2015-033).

5. References

[1] Fattah, I.M.R., Masjuki, H.H, Kalam, M., Wakil, M.A., Ashraful, A.M. and Shahir, S.A., "Experimental investigation of performance and regulated emissions of a diesel engine with Calophylluminophyllum biodiesel blends accompanied by oxidation inhibitors", *Energy Conversion and Management*, vol. 83, pp. 232-240, 2014.

[2] Imtenan, S., Masjuki, H.H., Varman, M., Kalam, M.A., Arbab, M.I., Sajjad, H. and Ashrafur Rahman, S.M., "Impact of oxygenated additives to palm and jatropha biodiesel blends in the context of performance and emissions characteristics of a light-duty

diesel engine", *Energy Conversion and Management*, vol. 83, pp. 149-158, 2014.
[3] Mofijur, M., Masjuki, H.H., Kalam, M.A., Atabani, A.E., Arbab, M.I., Cheng, S.F. and Gouk, S.W., "Properties and use of Moringaoleifera biodiesel and diesel fuel blends in a multi-cylinder diesel engine", *Energy Conversion and Management*, vol. 82, pp. 169-176, 2014.
[4] Ong, H.C., Masjuki, H.H., Mahlia, T.M.I., Silitonga, A.S., Chong, W.T. and Leong, K.Y., "Optimization of biodiesel production and engine performance from high free fatty acid Calophylluminophyllum oil in CI diesel engine", *Energy Conversion and Management*, vol. 81, pp. 30-40, 2014.
[5] Xue, Y., Zhao, Z., Xu, G., Lian, X., Yang, C., Zhao, W., Ma, P., Lin, H. and Han, S., "Effect of poly-alpha-olefin pour point depressant on cold flow properties of waste cooking oil biodiesel blends", *Fuel*, vol. 184, pp. 110–117, 2016.
[6] Gharehghani, A., Mirsalim, M. and Hosseini, R., "Effects of waste fish oil biodiesel on diesel engine combustion characteristics and emission, *Renewable Energy*, vol. 101, pp. 930-936, 2017.
[7] Mehrasbi, M.R., Mohammadi, J., Peyda, M. and Mohammadi, M., "Covalent immobilization of Candida antarctica lipase on core-shell magnetic nanoparticles for production of biodiesel from waste cooking oil", *Renewable Energy*, vol. 101, pp. 593-602, 2017.
[8] Moecke, E.H.S., Feller, R., dos Santos, H.A., Machado, M.M., Cubas, ALV, Dutra, A.R.A., Santos, L.L.V. and Soares, S.R., "Biodiesel production from waste cooking oil for use as fuel in artisanal fishing boats: Integrating environmental, economic and social aspects", *Journal of Cleaner Production*, vol. 135, pp. 679-688, 2016.
[9] Demir, B., "Construction of a small sized biodiesel system, engine performance tests, energetic and exergetic evaluation of the obtained cottonseed oil methyl ester", *Ege University Graduate School of Natural Sciences, Phd Thesis,* pp. 3-4; 73-76; 101-220, 2009, İzmir, Turkey.
[10] Patterson, J., Hassan, M.G., Clarke, A., Shama, G., Hellgardt, K. and Chen, R., "Experimental study of DI diesel engine performance using three different biodiesel fuels", *SAE*, 2006-01-0234, 2006.
[11] Bolat, A., "The affects of biodiesel on engine performance of an MID-HP agricultural tractor and the significance of biodiesel for Turkey", Trakya University Graduate School of Natural Sciences, Master's Thesis, pp. 30-38, 2007, Tekirdağ, Turkey.
[12] Utlu, Z. and Koçak, M.S., "The effect of biodiesel fuel obtained from waste frying oil on direct injection diesel engine performance and exhaust emissions", *Renewable Energy,* vol. 33(8), pp. 1936-1941, 2008.
[13] Aktaş, A. and Şahin, Ö., "Use of hydrogen to enhance the performance and emissions of a diesel/biodiesel blending fuelled compression ignition engines", *UludağÜniversitesiMühendislik-MimarlıkFakültesiDergisi,* vol. 14(1), pp. 87-97, 2009.
[14] Van Gerpen, J.H., Peterson, C.L. and Goering, C.E., "Biodiesel: An alternative fuel for compression ignition engines", *The American Society of Agricultural and Biological Engineers*, Lecture No:31, pp.1-22, 2007.
[15] Yücesu, H.S. and İlkılıç, C., "Effect of cotton seed oil methyl ester on the performance and exhaust emission of a diesel engine", *Energy Sources - Part A*, vol. 28(4), pp. 389-398, 2006.
[16] Çengelci, E., Bayrakçeken, H. and Aksoy, F., "Hayvansalvebitkiselyağlardaneldeedilenbiyodizelindizelyakıtıilekarşılaştırılma

sı”, *TaşıtTeknolojileriElektronikDergisi,* vol. 3(1), pp. 41-53, 2011.
[17] Liaquat, A.M., Kalam, M.A., Masjuki, H.H., and Jayed, M.H., “Engine performance and emissions analysis using “Envo Diesel” and coconut biodiesel blended fuel as alternative fuels”, *2nd International Conference on Environmental Science and Technology,* vol. 1, pp. 168-172, 2001, Singapore.
[18] Lesnik, l., Iljaz, J., Hribernik, A. and Kegl, B., “Numerical and experimental study of combustion, performance and emission characteristics of a heavy-duty DI diesel engine running on diesel, biodiesel and their blends”, *Energy Conversion and Management,* vol. 81, pp. 534-546, 2014.
[19] İlkılıç, C., Aydın, S., Behçet, R. and Aydın, H., “Biodiesel from safflower oil and its application in a diesel engine”, *Fuel Processing Technology*, vol. 92(3), pp. 356-362, 2011.
[20] He, B., Shuai, S., Wang, J. and He, H., “The effect of ethanol blended diesel fuels on emissions from a diesel engine”, *Atmospheric Environment,* vol. 37(35), pp. 4965-4971, 2013.
[21] Özener, O., Yüksel, L., Ergenç, A.T. and Özkan, M., “Effects of soybean biodiesel on a DI diesel engine performance, emission and combustion characteristics”, *Fuel,* vol. 115, pp. 875-883, 2014.
[22] Enweremadu, C.C., Rutto, H.L. and Peleowo, N., “Performance evaluation of a diesel engine fueled with methyl ester of shea Butter”, *World Academy of Science, Engineering and Technology,* vol. 79, pp. 142-146, 2011.
[23] Parekh, P.R. and Goswami, J., “Emission and performance of diesel engine using waste cooking oil bio diesel blends-review”, *Journal of Engineering Research and Studies,* vol. 3(1), 2012.
[24] Swaminathan, C. and Sarangan, J., “Performance and exhaust emission characteristics of a CI engine fueled with biodiesel (fish oil) with DEE as additive”, *Biomass and Bioenergy,* vol. 39, pp. 168-174, 2012.
[25] Chauhan, B.S. Kumar, N. and Cho, H.M., “A study on the performance and emission of a diesel engine fueled with Jatropha biodiesel oil and its blends”, *Energy,* vol. 37(1), pp. 616-622, 2012.
[26] Prasad, L., Pradhan, S., Das, L.M. and Naik, S.N., “Experimental assessment of toxic phorbol ester in oil, biodiesel and seed cake of Jatrophacurcas and use of biodiesel in diesel engine”, *Applied Energy,* vol. 93, pp. 245-250, 2012.
[27] Peterson, C.L. and Hustrulid, T., “Carbon cycle for rapeseed oil biodiesel fuels”, *Biomass and Bioenergy,* vol. 14(17-18), pp. 91-101, 1998.
[28] Dizge N., Canlı O. and Karpuzcu, M., “ Biyodizelkullanımınınçevreiçinönemi, *3. YenilenebilirEnerjiKaynaklarıSempozyumuveSergisi*, 2005, Mersin, Turkey.
[29] Çelikten, İ. and Gürü, M., “Petrodizelvekanolabiyodizeliperformansveemisyonkriterlerininmanganesaslıkatkımaddeleriylegeliştirilmesi”, *GaziÜniversitesiMühendislikMimarlıkDergisi*, vol. 26(3), pp. 643-648, 2011.
[30] Randazzo, M.L. and Sodre, J.L., “Exhaust emissions from a diesel powered vehicle fuelled by soybean biodiesel blends (B3–B20) with ethanol as an additive (B20E2–B20E5)”, *Fuel,* vol. 90(1), pp. 98-103, 2011.
[31] Rounce, P., Tsolakis, A. and York, A.P.E., “Speciation of particulate matter and hydrocarbon emissions from biodiesel combustion and its reduction by aftertreatment”, *Fuel,* vol. 96, pp. 90-99, 2012.
[32] Tan, P., Hu, Z., Lou, D. and Li, Z., “Exhaust emissions from a light-duty diesel engine with Jatropha biodiesel fuel”, *Energy,* vol. 39(1), vol. 356-362 2012.
[33] Dhar, A., Kevin, R. ve Agarwal, A.K., “Production of biodieselfromhigh-FFA neemoil and itsperformance, emission

and combustioncharacterization in a singlecylinder DICI engine", *FuelProcessingTechnology,*vol. 97, pp. 118-129, 2012.