# ANALYSIS OF THE EFFECT OF SME B20 FUEL ON THE DIESEL ENGINE PERFORMANCE'S SOOT AND $NO_X$ EMISSIONS AT DIFFERENT INJECTION ADVANCES WITH DIESEL RK

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## ABSTRACT

*The increasing energy need, the uneasiness that fossil sourced fuel might be exhausted, the increasing environment awareness and requirements have directed the researches to search for alternative fuels and to studies related to decreasing the emission of pollutants like $CO_2$, HC, NOx, soot and SOx. Diesel engines are presently being used intensively in different sectors. The most important among the diesel engine sourced pollutants are NOx and soot emissions. These studies are both time and cost intensive for the researchers. There are in general different commercially used software in the market. The operating logic of these software is based on the 1st law of thermodynamics. In this study we conducted is standard B20 fuel modelled at different injection advances (16°KMA, 20°KMA, 24°KMA and 28°KMA) assessed with diesel fuel at standard injection advance with the Diesel-RK software in the program library. As a result, it is observed that the power loss has decreased by nearly 1-2% and the SFC increased by nearly 2% for the B20 fuel at 28°KMA compared with diesel fuel. It is revealed that there was an NOx emission increase of nearly 8% and a decrease of the soot emission by 3% to 33%.*

**Keyword : -** *Diesel RK, Diesel Engine, Injection Advances, Biodiesel, Simulation.*

## 1. INTRODUCTION

Petrol fuels meet many of our basic energy needs in the industrial development, transportation, agricultural sectors and many others. These fuel reserves are being rapidly exhausted due to the excess consumption. The researches are also dealing with the reduction of the increase of pollutant emissions like $CO_2$, HC, NOx, and SOx along with the limited usability of raw petrol [1]. Until present were the most studies with regards to the fight against the effects of the climate change focussed on the reduction of the greenhouse gas emissions or the conversion of these gases into lesser harmful ones for the climate change effects [2]. Along with this, the scarcity of traditional fossil sourced fuels, the pollutants generated by the combustion, their increasing costs and emissions turn alternative fuels more attractive [3,4]. Beside this, that hope giving digestive herbal oils are being used as an alternative to the expensive and exhausting fossil fuels is directing the researchers to such studies [5]. But many studies note on a worsening of the engine performance in case of the usage of alternative fuels, particularly of bio-diesel. It is advocated that the reason for this is that the lower heat value of bio-diesel fuel is low and that its density and viscosity is high [6]. Compression combusted engines are widespread used in different works and sectors due to their perfect operability and their thermal efficiency. But carbon monoxide, nitrogen oxide, soot and other harmful exhaust gases at compression combusted engines are among the important of the air pollutants [7,8]. The most important two emissions of diesel engines are soot and nitrogen oxide (NOx) emissions [9]. There are diverse methods in order to control NOx emission. Ilkiliç C. et al. have examined in the study they conducted the development of nitrogen oxides at diesel engines and their control methods at different engine parameters and noted that the NOx generation decreased at these parameters, but that there was an increase for the other parameters [10]. Beside this, Ozdalyan B. et al. have examined the influence of the static injection advance at a single cylinder, direct injection engine on the performance and emissions. The conducted search has performed the test at 15,19,23,27,31° KMA at 20%, 40%, 60%, 80% and 100% flap opening and determined that a decrease of the injection advance to 19 KMA resulted in an increase of the engine moment and effective power and a decrease of the specific fuel consumption and the emissions [11]. Yaşar A. et al. have with different injection angles (15°, 25°, 35°, 45°, 55°) and different compression ratios (16:1, 18:1, 20:1 ve 22:1) at these parameters with different piston case structures (ZMZ-514 and 10D100), different parameters (RME B100 Diesel No 2) with a 4-hole injection nozzle with the DIESEL-RK simulation program and have achieved a high power by the increase of the injection angle (55°) at ZMZ-514 piston case structure and by using standard diesel fuel. Therefore, the ZMZ-514 maximal burning temperature was higher at the 10D100 piston case structure. Contrary to 55° injector angle are a define fuel consumption change ZMZ-514, the fuel consumption values obtained from the piston with a piston case structure have indicated in the simulation that they were lesser than those of the piston with a 10D100 piston case structure at all compression rates [12]. Thermodynamic modelling are mainly based on the first law of thermodynamics and are used in order to analyse the performance features of engines. Pressure, temperature and other necessary features are evaluated angular according to time, with other words, according to the angle of the crank rod. Beside this, it has to be taken into consideration by using the empiric equations obtained from the engine friction and heat transfer experiments [13]. The thermodynamic software DIESEL-RK calculations are being used for performance optimization at compression, combustion engines [14].

## 2. MODELLING

DIESEL-RK is a modelling and simulation software particularly developed for the simulation of internal combustion engines. The DIESEL-RK software is developed by the Internal Combustion Engines Department of the Moscow State Technical University in 1981-82. It is particularly designed with regards to optimizing the operating processes of internal combustion engines with its imitation and increasing. This software allows modelling by using many parameters including torque curves, engine performance estimations, fuel consumption estimations, emission analysis and multiple injection at DI diesel engine models, injection design and location and beside these the optimization of piston chamber form [15]. This performed study is modelled with the DIESEL-RK software at standard injection advance, different engine cycles as a mixture of D2 fuel and D2+SME (80% D2 + 20% SME) and the result of the study is assessed as power, moment and SFC and the performance obtained with the fuel mixture providing the closest performance to the diesel fuel model and the performance obtained from the diesel fuel modelled at the standard injection advance are evaluated with regards to the soot and $NO_X$ emissions.

The features of the fuels modelled in the simulation are given in Table 1 and the engine features are given in Table 2.

**Table-1:** The physical properties of the modelled fuel.

| The physical properties of the fuel | D2 | SME B20 |
|---|---|---|
| C (carbon) | 0.87 | 0.8496 |
| H (hydrogen) | 0.126 | 0.1245 |
| O (oxygen) | 0.004 | 0.02591 |
| The lowest calorific value (MJ/kg) | 42.5 | 41.18 |
| Cetan Number | 48 | 48.68 |
| Density (kg/m3) | 830 | 841 |
| Viscosity (Pa.s) | 0.003 | 0.00334 |

**Table-2:** The Properties of Engine Modelled

| Engine Type | Four-Stroke Diesel Engine |
|---|---|
| Cylinder / Number of Valves | 1 cylinder / 2 valve |
| Diameter x Stroke | 70 mm x 55mm |
| Compression Ratio | 20 |
| Max. Engine Speed | 3000 1/min |
| Cooling System | Air Colled |
| Piston Case Type | ZMZ 514 |

## 3. RESULTS

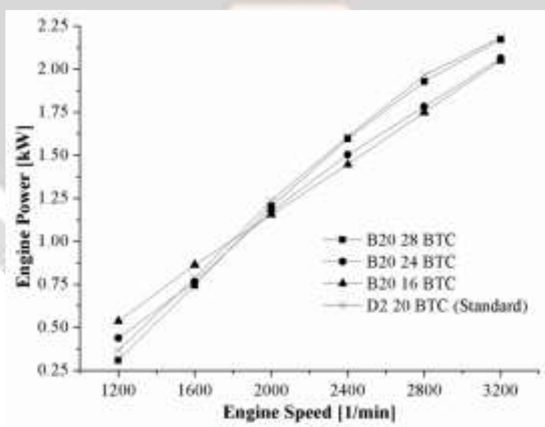


**Fig-1:** The effect of injection advances of the engine power.

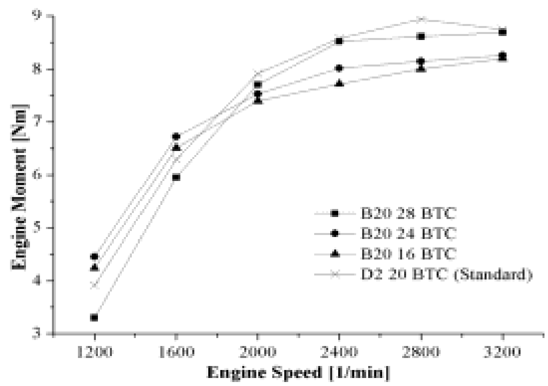


**Fig-2:** The effect of injection advances of the engine moment.

Figure 1 and Figure 2 indicates the effect of B20 fuel on the power and moment changes at different injection advances. It is seen that there is at standard diesel fuel and B20 fuel modelling at standard engine parameters a power loss of nearly 4% and that there is a loss of 1-2% at all engine speeds above 2000 rpm compared with standard diesel fuel when the injection advance is 28°KMA. It is seen that there is a decrease of nearly 6-7% at the engine power loss by decreasing the injection advance. The decrease of the injection advance results in an increase of the engine power. There is a decrease of the engine power and moment due to the fact that the turbulence is low when the injection advance is increased (28 °KMA) at low engine speeds since the internal pressure of the cylinder is low during the injection at low engine speeds and the fuel atomization is affected during the injection of high density and viscosity fuel. It is seen that the engine power and moment increases when the injection advance is decreased under the same conditions. This situation, that the compression end pressure is high and the air resistance corresponding to the injected fuel is high, influences the drop diameter of the injected fuel [17,21]. Whilst the ignition delay decreases by the increase of the injection advance up to a define point, the further increase results in the extension of the ignition period [18]. But since the time for the burning of the fuel at high engine speeds is insufficient, results the increase of the injection advance in that the fuel gets enough time to burn and consequently in some improvement of the engine power, moment and SFC [18].

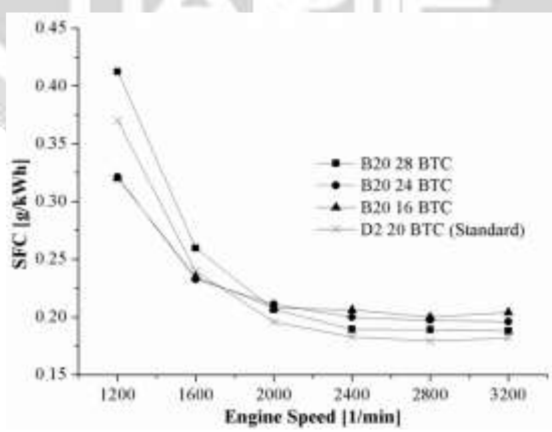


**Fig-3:** The effect of injection advance of the SFC.

Figure 3 shows the effect of the injection advance of the SFC. An increase of maximal 11% and minimal 2% of the standard injection advance is determined depending on the changing engine speeds when B20 fuel is being modelled (Figure 3). The specific fuel consumption changes between nearly 1-3% at high engine speeds fort he same fuel type with an increased injection advance (28° KMA). In this case, whilst there is an increase of the mean specific fuel consumption of 6.3% according to the varying speeds of the engine at standard injection advance, it decreases to 2.6% at the mean varying engine speeds by the increase of the advance to 28°KMA. With other words, a mean increase of 2.6% is seen at the modelling of B20 fuel at 28°KMA compared with diesel fuel modelling at a standard injection advance. This increase at the fuel consumption reveals that more fuel needs to be used in order to achieve the same energy due to the fact that the lower heating value of bio-diesel is lower than that of diesel fuel [6].

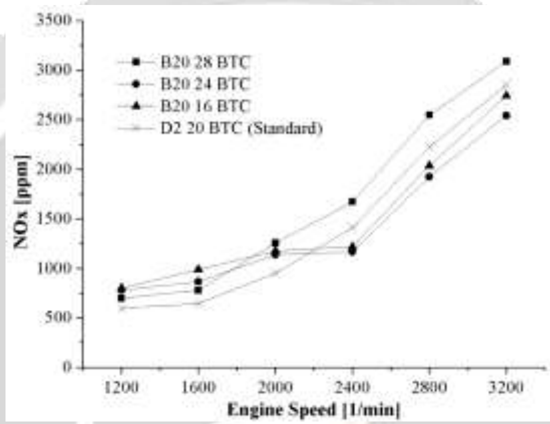


**Fig-4:** The effect of injection advances on NOx emissions.

Figure 4 shows the effect of different injection advances on the NOx emissions. It is seen that the NOx emissions increase by the increase of the engine speed, too. It is seen that the NOx emissions at 28°KMA injection advance increase by the increase of the high engine speeds. The increase of the post-burning temperatures by the increasing engine speed result in the increase of the NOx emissions. The excess of the oxygen and nitrogen gases in the burning chambers of diesel engines result in NOx emission at high flame temperatures (>1800°C) [19]. By an injection advance 28°KMA, it is seen that, when modelled with B20 fuel, there is an increase by 8-18% at standard injection advance compared with diesel fuel modelling, and that the maximal increase occurs at an engine speed of 2400 rpm. it is seen that The minimum soot emission is obtained in engine speed (2800 rpm) and in NOx emissions in the same injection advance an increase of 11% and soot value is 33%. Diesel engines are engines operating with a poor mixture. Beside this, it is known the usage of bio-diesel fuel will result in the increase of the NOx emissions due to that the oxygen quantity in bio-diesel is high compared with standard diesel fuel [6].

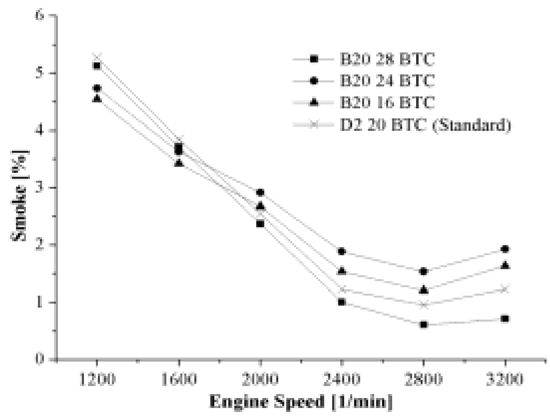


**Fig-5:** The effect of injection advances on soot emissions.

Figure 5 shows the effect of different injection advances on the soot emissions. It is to be seen that the soot emission decreases at all injection advances by the increase of the engine speed. The least emission is seen at 2800 rpm engine speed at 28°KMA. It is seen that nearly at all engines an improvement between 3% to 33% is achieved with the B20 fuel, 28°KMA modelled with Standard spraying advance by the increase of the injection advance. It is seen that there is an improvement of nearly 33% with the modelling at an engine speed of 3200 rpm at 28°KMA with B20 fuel. It is seen that in the engine speed and injection advanced it is obtained NOx emissions to the maximum to be a decrease soot emissions of 32% and NOx value is 18%. The improvement ratio for the soot emission decreases by the decrease of the engine speed. The soot emission is constituted by the non-burnt carbon atoms resulting from the deficient burning. The soot development depends on the temperature in the burning chamber, the oxygen quantity and time. The soot emission will increase when the soot particles cannot find sufficient heat, oxygen and time in the burning chamber [20]. Due to the fact that the fuel will burn regionally with a rich mixture as a result of the low turbulence inside the cylinders at low motor speeds, this will result in the increase of the soot emission at low speeds, but the availability of free oxygen in bio-diesel prevents this increase, even if only partially.

## 4. CONCLUSIONS

It is noted in the literature that the engine performance will decrease a little when bio-diesel fuel is being used as an alternative fuel at diesel engines [6,12,16,18]. The fuel with the closest performance to diesel fuel is, when assessing with regards to the engine performance, the fuel containing lesser bio-diesel [16].

It is seen that there was an engine power loss of nearly 1% compared with diesel fuel modelling at standard parameters by the increase of the injection advance when B20 fuel is being used. The modification of different engine parameters at alternative fuel usage can be decreased to ignorable values for alternative fuels with regards to the engine performance.

The increase of the injection advance when using B20 fuel will also result in the increase of the NOx emission. Beside this, it is seen that there are improvements at the soot emission under these conditions compared with diesel fuel. The emission value can be decreased by different methods used in order to decrease the NOx emissions.

A better performance and emission result can be achieved at diesel engines by the modification of the joint application of the change of different parameters affecting the burning reaction along with the change of the injection advance when a bio-diesel mixture is being used.

## 5. REFERENCES

[1] Sunil K., Chaube A., and Jain S.K., "Experimental evaluation of CI engine performance using diesel blended with Jatropha biodiesel," Intl J. Energy Environ, 3(2012), 471-484, 2016.
[2] McNutt M., "Climate Intervention: Possible Impacts on Global Security and Resilience," Engineering, 2(1), 50-51, 2016.
[3] Misra R. D., and Murthy M. S., "Blending of additives with biodiesels to improve the cold flow properties, combustion and emission performance in a compression ignition engine—A review," Renewable and Sustainable Energy Reviews, 15(5), 413-2422, 2011.
[4] Jinlin X., Grift T.E., and Hansen A.C., "Effect of biodiesel on engine performances and emissions," Renewable and sustainable energy reviews, 2011, Vol. 15(2), pp. 1098-1116.
[5] Al-Dawody M.F., and Bhatti S.K., "Theoretical Modeling of Combustion Characteristics and Performance Parameters of Biodiesel in DI Diesel Engine with Variable Compression Ratio," International Journal of Energy And Environment, 4(2), 231-242, 2013.
[6] Ozer S., Vural E., ve Ozdalyan B. "The Use Of Canola Oil Methyl Ester - Diesel Fuel Mixture Effects On Diesel Engine Performance And Emissions," Electronic Journal of Vehicle Technologies (EJVT), 3(1), 9-18, 2011.
[7] Xing-cai L., Jian-guang Y., Wu-gao Z., and Zhen H., "Effect of Cetane Number Improver on Heat Release Rate And Emissions of High Speed Diesel Engine Fueled with Ethanol–Diesel Blend Fuel," Fuel, 8(3), 13–20, 2004.
[8] Smith P.C., Ngothai Y.Q., Nguyen D. and O'Neill B.K., "Improving the Low-Temperature Properties of Biodiesel, Methods and Consequences, "Renewable Energy, 3(5), 1145–1151, 2010.
[9] Haşimoglu C., and Icingur Y. "Control Strategies for Diesel Engines," Selcuk Technical Online Magazine, Vol. 1, ISSN 1302-6178, 2000.
[10] Ilkilic C., Behçet R. ve Aydın S. "NOx Formation in Diesel Engines and Control Methods," The 5th International Technology Symposium (IATS'09), May 13-15, Karabuk, s. 2009, 2062-2066, Turkey.
[11] Ozdalyan B., Vural E. ve Ozer S. "Experimental Analysis of The Effects of Advancing on Engine Performance and Exhaust Emissions in a Small Volume Diesel Engine," Electronic Journal of Vehicle Technologies (EJVT), 3(3), 1-10, 2011.
[12] Yasar A., Ozcanli M., Serin H. and Aydin K. "Compression ratio and injection angle effect on performance and emissions of a diesel engine fuelled with rapeseed biodiesel and diesel fuel, International Proceedings of Chemical," Biological and Environmental Engineering (IPCBEE), 7(3), 20-24, 2014.
[13] Hamdan M.A. and Khalil R.H., "Simulation of Compression Ignition Engine Powered by Biofuels," Energy Conversion and Management, Vol. 5(1), pp. 1714-1718, 2010.
[14] Nasim M.N., Yarasu, R.B. and Yamin J., "Simulation of CI engine powered by neat vegetable oil under variable fuel inlet temperature," Indian Journal of Science and Technology, 3(4), 387-392, 2010.
[15] Siddique S.K.A. and Reddy K.V.K., "Theoretical Investigation on Combustion Chamber Geometry of DI Diesel Engine to Improve the Performance by Using Diesel-RK," International Journal of Innovative Technology and Exploring Engineering (IJITEE), 6(2), 92-98, 2015.
[16] Celik M.B. and Simsek D. "The determination of optimum injection pressure in an engine fuelled with soybean biodiesel/diesel blend," Thermal Science, 18(1), 229-238, 2014.
[17] Safgonul B., Ergeneman M., Arslan H.E. and Sorusbay C., "Internal Combustion Engines," Birsen Publisher, s. 189, 2013.
[18] EL-Kasaby M. and Nemit-allah Medhat A., "Experimental investigations of ignition delay period and performance of a diesel engine operated with Jatropha oil biodiesel," Alexandria Engineering Journal, 52(2), 141-149, 2013.
[19] Agarwal D., Kumar L., Kumar Agarwal A., Performance evaluation of a vegetable oil fuelled compression ignition engine, Renewable Energy, 33, 1147-1156, 2008.
[20] Çelikten İ. and Arslan M.A., "Investigation Of Diesel Fuel, Rape Oil And Soybean Oil Methyl Esters Effects On A Direct Injection Diesel Engine Performance And Emissions," J. Fac. Eng. Arch.Gazi Univ, 23(4): 829-836, 2008.
[21] Vural E., Şimşek D., Ozer S., "The Analysis of the Effect of Diesel Fuel Additive 5%, Compression Ratio and Injection Pressure on the Performance with Diesel-RK Programme," International Conference on Natural Science and Engineering (ICNASE'16), 19-20, pp. 2125-2135, March 2016, Kilis /Turkey.