# Investigation of The Application of Water Injection to The Performance of Commonrail Diesel Engine

Fadli Rozaq[1*] , Willy Artha Wirawan[2] , Natriya Faisal Rachman[3] , Arif Darmawan[4]

[1,2,3,4]*Railway Mechanics Technology Indonesian Railway Polytechnic Jalan Tirta Raya, Madiun, Indoneisa*
fadli@pengajar.ppi.ac.id

**Abstract**. Water injection is one of the technologies to improve engine performance. The purpose of this research is to investigate the application of water injection in a commonrail turbo diesel engine. The experimental method is used in this research by testing the power and torque of the diesel engine in conditions without the application and with the application of water injection. The injected water pressure is 100 psi with an injector nozzle diameter of 0.2 mm injected through the intake manifold. The experimental results show an increase in diesel engine power and torque in the application of water injection.

Keyword: Water Injection, Diesel Engine, Commonrail

## 1. Introduction

The diesel engine is an internal combustion engine in which the combustion process of the air and fuel mixture occurs by the high temperature generated by the compression level of the engine itself. Therefore, diesel engines do not require spark plugs to burn the air and fuel mixture.[1]. The level of durability of diesel engines is quite good and a good level of efficiency makes diesel engines widely used in various sectors. Starting from the small industry sector, transportation, to large industries.

Efforts to improve the performance of diesel engines have been made by many diesel engine manufacturers. This improvement in diesel engine performance is expected to be able to make diesel engines more efficient in terms of fuel use, more environmentally friendly, and can issue large power.[2]. Technology development for diesel engines has also been widely developed. One of them is the development of turbo systems and fuel systems in diesel engines [3].

The development of diesel engine fuel systems, which initially used conventional injection systems, has now widely used commonrail systems.[4]. This commonrail system allows more accurate fuel distribution settings compared to conventional systems. The timing, duration, and fuel injection pressure can be controlled electrically. The application of the commonrail system in diesel engines is claimed to be able to improve performance.[5]. Evident from the various studies that have been conducted to test this commonrail system.


A. Pradipta et al. (eds.), *Proceedings of the 2nd International Conference on Railway and Transportation 2023 (ICORT 2023)*, Advances in Engineering Research 231,
https://doi.org/10.2991/978-94-6463-384-9_21

The development of diesel engine technology does not only stop at the fuel system. Diesel engines are also applied turbo technology in order to accommodate the need for maximum air discharge into the combustion chamber. Currently, various types of turbos have been developed. One of them is variable geometry turbo technology[6]. This technology allows variations in the turbine in the turbo so that it can be utilized to get a good boost effect [7] The turbo work system utilizes exhaust gas pressure to rotate the turbine connected to the compressor so that it will force air to enter the combustion chamber. Compressed air and exposed to the heat of the exhaust gas makes the air temperature increase.[8]. High air temperature will reduce the density of air. Conditions will affect the combustion that is less than optimal.

Efforts that can be made to reduce the temperature of the air entering the combustion chamber in a diesel engine that uses a turbo is the addition of an intercooler device.[9]. The system works by flowing compressed air from the turbo to the intercooler so that a heat exchanger occurs with the air flow from outside before entering the combustion chamber. In high outside air temperature conditions, sometimes this intercooler cannot work optimally.

Water injection is one of the technologies being developed in order to improve engine performance [10]. The way this system works is by introducing pure water into the combustion chamber[11]. Water injection technology has currently been applied but is still limited to premium vehicles and also vehicles for competition or racing purposes. The injection of water into the intake manifold or into the combustion chamber is expected to reduce air temperature and increase air density.[12]. Of course, with increasing air density, volumetric efficiency can be achieved and have an impact on optimal combustion. So in this study, an experiment will be carried out to apply water injection to a coomonrail turbo diesel engine used in private vehicles.

## 2. Research Methods

### 2.1 Literature Study

The study in this research uses materials sourced from literature studies. The study materials come from written sources (research journals, books, documents) as well as from other sources relevant to the research topics and problems. The next step after studying the literature is to determine the experimental design to be carried out. The data collection technique is to conduct experiments with diesel engines that will be given treatment and without treatment. This research produces diesel engine performance data in the form of power and torque. The data obtained is then processed, analyzed, and concluded.

### 2.2 Preparation of Tools and Materials

In this study, experiments were conducted on diesel engines by providing water injection into the intake manifold. The necessary equipment includes a commonrail

diesel engine with code 2GD-FTV with VNT Turbo, water pump, hose, 0.2mm injector nozzle, and chassis dynamometer.

### 2.3 Experiment Design

Experiments were conducted by measuring the power and torque output of the diesel engine. First, power and torque measurements were made on the condition of the engine without receiving treatment. The next measurement of power and torque was carried out in the condition that the engine received treatment in the form of applying water injection through the intake manifold. In each condition both with and without treatment, data were taken three times or three runs on the dynamometer. The injected water pressure is 100 psi with an injector nozzle diameter of 0.2 mm. The power and torque data used are the measurement results of the power supplied to the wheels or wheel horse power. The data taken is the power and torque data generated at each RPM range.

## 3. Results And Discussion

### 3.1 Power Testing Results

Power testing was carried out in two conditions, namely without the application of water injection and with the application of water injection. Each condition was tested three times. The results of power testing in the condition without treatment can be seen in Figure 1.

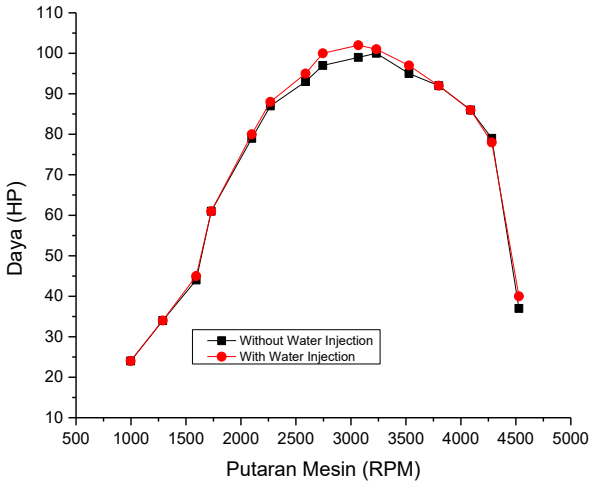


Image 1. Comparison of engine power under conditions without and with the application of *water injection*.

The graph in Figure 1 shows that the diesel engine that gets the application of water injection shows a higher power trend compared to the power trend produced by the diesel engine in the condition without the application of water injection. The highest

peak power in the condition without the application of water injection is 100 HP and the highest power in the application of water injection is 101 HP. This shows that there is an increase in diesel engine power after the application of water injection.

### 3.2 Torque Testing Results

Torque testing was carried out in two conditions, namely without the application of water injection and with the application of water injection. The results of the torque test can be seen in Figure 2.

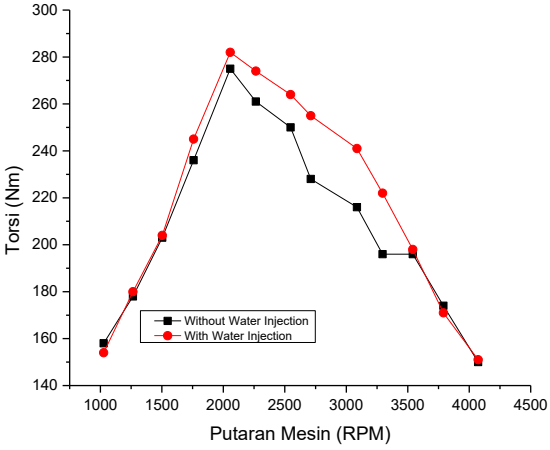


Image 2Comparison of engine torque without and with the application of *water injection*.

Figure 2 shows the results of engine torque testing with water injection treatment. The trend of the power results shows an increase in peak torque when compared to the condition without the application of water injection treatment. The peak torque in the condition without water injection application is 275 Nm and the peak torque in the condition with water injection application is 280 Nm. This result is proportional to the increase in engine power under the condition of applying water injection [16] [17].

### 3.3 Discussion

The phenomenon of increasing power and torque in water injection with an injector nozzle diameter of 0.2 mm shows that water injection can have a positive effect on increasing engine power and torque. In line with research conducted by Zang et.al which explains that water and biodiesel have different boiling points[13]. Water has a lower boiling point than biodiesel. The boiling point of water is $100^0$ C and the boiling point of biodiesel is $180^0$ C - 360 C $^0$(S. Li et al., 2020).. The compression stroke temperature of a diesel engine is about $650^0$ C, the combustion temperature of a diesel engine is $1427^0$ C, and the compression pressure of a diesel engine is 580 psi/39.9 bar.

This lower boiling point of water causes the evaporation rate of water to be faster than that of biodiesel. The water molecules will reach the *superheated* stage faster and produce expansion of the water vapor. This expansion of water vapor will produce microexplosions. The micro-explosions that occur produce the phenomenon of secondary atomization process in the fuel. The degree of atomization of the fuel will be better so that the fuel and air are easier to form a homogeneous mixture. A schematic diagram of the secondary atomization phenomenon can be seen in Figure xx.

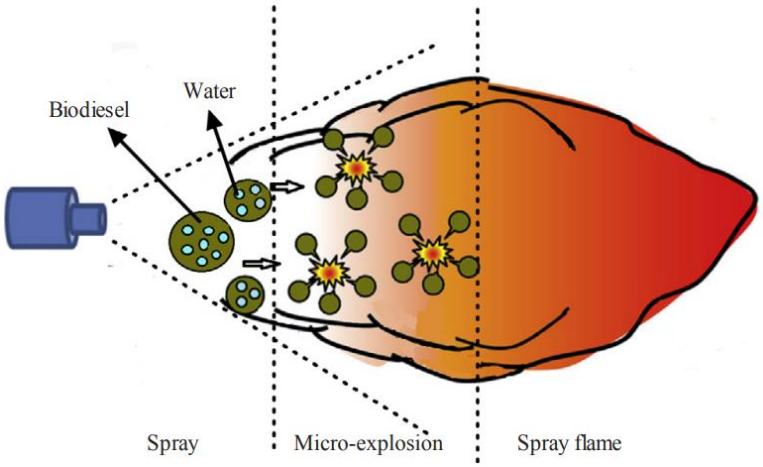


Image 3. Schematic of water vapor micro explosion in secondary atomization process[15]

## 4. Conclusion

After processing and analyzing the data from the experimental results of applying water injection to a commonrail turbo diesel engine, it can be concluded that the application of water injection can have an impact on increasing power and torque in diesel engines. However, with these results it is still necessary to conduct further research to determine the negative impact caused by the application of water injection.

## 5. Acknowledgments

The author would like to express his gratitude to the entire academic community of the Indonesian Railway Polytechnic who have supported the completion of this research.

**REFERENCES**

[1] Y. Zhu and H. C. Frey, *Integrated gasification combined cycle (IGCC) systems*. Elsevier Masson SAS., 2012.

[2] M. Effendy, A. Surono, E. Saputra, and N. A. Nugraha, “Performance and smoke

opacity of compression-ignition engine using used-waste oil," *Case Stud. Therm. Eng.*, vol. 26, no. April, p. 101063, 2021, doi: 10.1016/j.csite.2021.101063.

[3] N. Li, W. Gao, and yunfeng HU, "Nonlinear Model Predictive Controller Design for Air System Control of Variable Geometry Turbocharged Diesel Engine," *IFAC-PapersOnLine*, vol. 51, no. 31, pp. 714–719, 2018, doi: 10.1016/j.ifacol.2018.10.163.

[4] I. Arsie, C. Pianese, and M. Sorrentino, "Control parameters optimization in automotive diesel engines via two zone modelling," *IFAC Proc. Vol.*, vol. 5, no. PART 1, pp. 425–432, 2007, doi: 10.3182/20070820-3-us-2918.00058.

[5] V. K. Shahir, C. P. Jawahar, P. R. Suresh, and V. Vinod, "Experimental Investigation on Performance and Emission Characteristics of a Common Rail Direct InjectionEngine Using Animal Fat Biodiesel Blends," *Energy Procedia*, vol. 117, pp. 283–290, 2017, doi: 10.1016/j.egypro.2017.05.133.

[6] J. E *et al.*, "Experimental investigation on performance and economy characteristics of a diesel engine with variable nozzle turbocharger and its application in urban bus," *Energy Convers. Manag.*, vol. 193, no. January, pp. 149–161, 2019, doi: 10.1016/j.enconman.2019.04.062.

[7] M. Sjerić, I. Taritaš, R. Tomić, M. Blažić, D. Kozarac, and Z. Lulić, "Efficiency improvement of a spark-ignition engine at full load conditions using exhaust gas recirculation and variable geometry turbocharger – Numerical study," *Energy Convers. Manag.*, vol. 125, pp. 26–39, 2016, doi: 10.1016/j.enconman.2016.02.047.

[8] S. Kaul, T. Joshi, and L. Varshney, "Analysis of hot air duct between turbocharger and intercooler," *Mater. Today Proc.*, vol. 43, pp. 719–725, 2020, doi: 10.1016/j.matpr.2020.12.846.

[9] L. Naser, D. Ilir, and L. Shpetim, "Modelling and Simulation of the Turbocharged Diesel Engine with Intercooler," *IFAC-PapersOnLine*, vol. 49, no. 29, pp. 237–242, 2016, doi: 10.1016/j.ifacol.2016.11.058.

[10] X. Tauzia, A. Maiboom, and S. R. Shah, "Experimental study of inlet manifold water injection on combustion and emissions of an automotive direct injection Diesel engine," *Energy*, vol. 35, no. 9, pp. 3628–3639, 2010, doi: 10.1016/j.energy.2010.05.007.

[11] Y. Zhuang *et al.*, "Investigation of water spray evolution process of port water injection and its effect on engine performance," *Fuel*, vol. 282, no. June, 2020, doi: 10.1016/j.fuel.2020.118839.

[12] F. Bedford, C. Rutland, P. Dittrich, A. Raab, and F. Wirbeleit, "Effects of direct water injection on di diesel engine combustion," *SAE Tech. Pap.*, no. 724, 2000, doi: 10.4271/2000-01-2938.

[13] Z. Zhang *et al.*, "Effects of low-level water addition on spray, combustion and emission characteristics of a medium speed diesel engine fueled with biodiesel fuel," *Fuel*, vol. 239, no. November 2018, pp. 245–262, 2019, doi: 10.1016/j.fuel.2018.11.019.

[14] S. Li, J. Liu, Y. Li, M. Wei, H. Xiao, and S. Yang, "Effects of fuel properties on combustion and pollutant emissions of a low temperature combustion mode diesel engine," *Fuel*, vol. 267, no. December 2019, 2020, doi: 10.1016/j.fuel.2020.117123.

[15] Z. Zhang *et al.*, "Effects of low-level water addition on spray, combustion and emission

characteristics of a medium speed diesel engine fueled with biodiesel fuel," *Fuel*, vol. 239, no. October 2018, pp. 245–262, 2019, doi: 10.1016/j.fuel.2018.11.019.

[16] Rozaq F, Artha Wirawan W, Hari Boedi W, Dadang Sanjaya A and Nurtanto M 2020 The influence of centrifugal particulate matter reducer on gas opacity and fuel consumption of inspection train *J Phys Conf Ser* 1700 012050.

[17] F. Rozaq, W. A. Wirawan, Barokah, M. Effendy, M. Nurtanto. An analysis of temperature treatment of biodiesel fuel on engine performance. *AIP Conf. Proc.* 2671, 020027 (2023). https://doi.org/10.1063/5.0114486