P-ISSN: 2776-7329, E-ISSN: 2776-7310
Proceedings
5th Vocational Education International Conference
Semarang, 13 July 2023

Optimization of Injection Duration to Increase the Substitution of CNG Fuel on a Diesel Dual Fuel Engine Operation at High Load

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ABSTRACT
The availability of fossil fuels is dwindling, encouraging the use of alternative fuels such as Compressed Natural Gas (CNG) in internal combustion engines. The dual fuel technology applied to diesel engines can replace diesel fuel as the main fuel. CNG fuel is used as a substitute fuel for diesel fuel. The purpose of this study is to optimize the injection duration so that it can increase the supply of CNG fuel into the cylinder so that it can replace diesel fuel with a greater amount. This research was carried out experimentally by optimizing the injection duration of CNG fuel from 70˚-150 ˚CA with 20˚ CA intervals on diesel dual fuel engine. The results showed that the duration of CNG injection of 110 ˚CA obtained maximum engine performance as indicated by the increase in maximum cylinder pressure of 71.18 bar and maximum heat release rate of 132.20 kJ/m³.˚CA and an increase in the substitution of CNG fuel by 66% on a diesel dual fuel engine operating at high load. This research also contributes to adding references to student learning in the energy conversion machine subject so that it can increase student knowledge in the field of renewable energy.

Keywords: *Injection duration, Cylinder pressure, Heat release rate, Fuel substitution.*

1. INTRODUCTION

Fossil fuel supplies are currently running low while the number of vehicles continues to increase every year. Based on data from the Central Bureau of Statistics, it is noted that in 2021 there will be an increase of 4% from the previous year. This data illustrates that the consumption of fossil fuels is increasing while fuel reserves are decreasing so that fuel scarcity is possible.

In order to reduce the consumption of fuel oil, an engine technology using two fuels was discovered, namely diesel dual fuel [citation needed]. A diesel engine that combines two fuels, namely diesel fuel and CNG fuel. The use of this technology has been widely carried out in previous studies [1]–[5] The advantage of this technology is that it utilizes alternative fuels as the main fuel, in this case CNG fuel so that the use of fuel oil can be reduced. Several previous studies that have used this technology are Bari and Hossain [6] conducted research with the aim of knowing the performance of diesel engines using dual fuels. The results showed that overall engine performance using CNG and diesel fuel was lower than using pure fuel. However, carbon dioxide (CO_2) emissions are lower in dual fuel diesel engines. Wategave et al. [7] conducted a study with the aim of knowing the combustion and emission characteristics of a dual fuel diesel engine. The results showed that the use of CNG and biodiesel fuels resulted in lower nitrogen oxide (NO_x) emissions and smoke from diesel engines using pure diesel fuel (100%). Carlucci et al. [8] conducted research to analyze combustion in direct injection diesel engines using CNG and Diesel fuels.

However, the use of dual fuels in diesel engines causes problems, namely a decrease in engine performance [2], [9], [10]. Cheenkahorn et al. [2] explained that the presence of LNG causes a decrease in volumetric efficiency because some of the pure air has been replaced by some of the gas, so that the compression pressure and temperature decrease, resulting in a slower premix velocity of pilot fuel. Papagiannakis et al. [11] explained that in a diesel dual fuel engines there is a decrease in the rate of heat release compared to a single fuel diesel engine at low and high loads. Nithyanandan et al. [12] also explained that the value of the rate of heat release in a diesel dual fuel engine is lower than that of a single fuel diesel, and the more CNG that is substituted

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Based on these problems, it is necessary to improve the performance of diesel dual fuel engines by optimizing the substitution of CNG fuel in diesel engines. Optimization of CNG fuel substitution is carried out by adjusting the injection duration of CNG (ID of CNG) so that this is a novelty of this research. The purpose of this research is to optimize the injection duration to increase the CNG substitution more in diesel dual fuel engines under high loads. Parameters analyzed are cylinder pressure and rate of heat release as an indication of engine performance.

2. METHOD

The research method used in this research is experimental. The research was conducted on a direct injection one-cylinder four-stroke diesel engine. Diesel engine with a capacity of 411 cc with a compression ratio of 18:1. The diesel engine is modified using dual fuel technology using Biodiesel and CNG fuels.

2.1 Fuels

The fuel used in this study is biodiesel and CNG fuels. Biodiesel fuel is injected directly into the combustion chamber as an ignition. CNG fuel is injected at the air inlet and this fuel is used as the main fuel. The characteristics of biodiesel and CNG fuel follow from previous studies [13], [14].

2.2 Experimental setup

The test was carried out on a dual fuel diesel engine equipped with measuring instruments. The test was carried out by varying the duration of the CNG fuel injection. The test parameters are shown in Table 1 as follows:

Table 1. Research parameters on diesel dual fuel engines.

Rotation (rpm)	Load (kW)	Injection duration of CNG (°CA)
2000	4	70
2000	4	90
2000	4	110
2000	4	130
2000	4	150

The results of the study were compared with the control variables. The control variable is testing on a standard diesel engine (single fuel). Tests on standard engines were carried out using Biosolar (B30) and Biodiesel (B100) fuels.

The measuring instrument used to determine cylinder pressure and heat release rate is the TMR combustion analyzer. The specifications of this measuring instrument follow from previous studies [13]. Before the research was carried out, the engine was heated first until it reached a working temperature of ± 80 °C. The experimental setup of this study is shown in Figure 1 below.

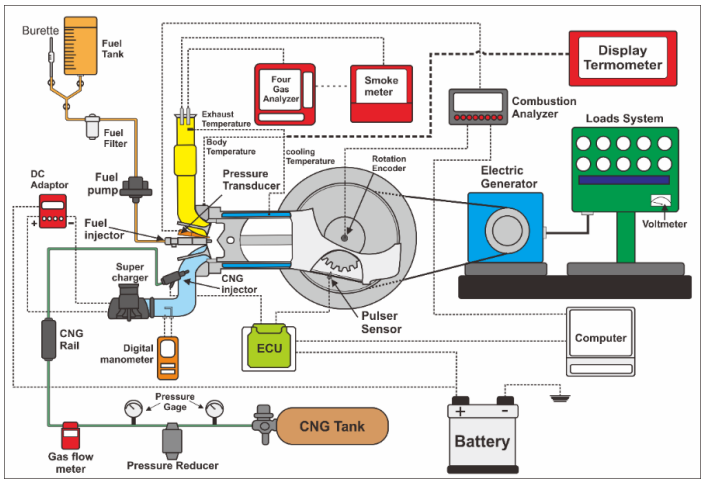

Figure 1. Experimental setup on a diesel dual fuel engines.

The results of this research were also disseminated to students of Mechanical Engineering at the Faculty of Engineering, Universitas Negeri Padang in order to increase student knowledge regarding diesel dual fuel engines technology through the energy conversion engine subject in the internal combustion engine section. After the dissemination was carried out, a measurement of the level of student understanding was carried out by making observation sheets related to student understanding of this material. The number of students who were sampled was 35 students.

3. RESULTS AND DISCUSSION

This section discusses optimizing the duration of CNG injection in a dual fuel diesel engine under high load (4kW) by analyzing combustion characteristics, namely cylinder pressure and heat release rate.

3.1 Cylinder pressure and heat release rate

Figure 2 explains the effect of CNG injection duration of CNG (ID of CNG) on cylinder pressure and rate of heat dissipation in diesel dual fuel engines under high load. The highest cylinder pressure was obtained at injection duration of CNG of 110 °CA with a value of 71.18 bar. Where with the engine load, the substitution of CNG fuel can be increased. At high load, the combustion temperature and pressure increase significantly, this was also shown in previous studies [3], [15]. This is due to the addition of a significant amount of fuel from biodiesel, resulting in more sources of fire points and a wider area of fire sources being formed in the combustion chamber, so that the premix combustion of biodiesel fuel increases significantly and results in high cylinder temperatures and pressures.

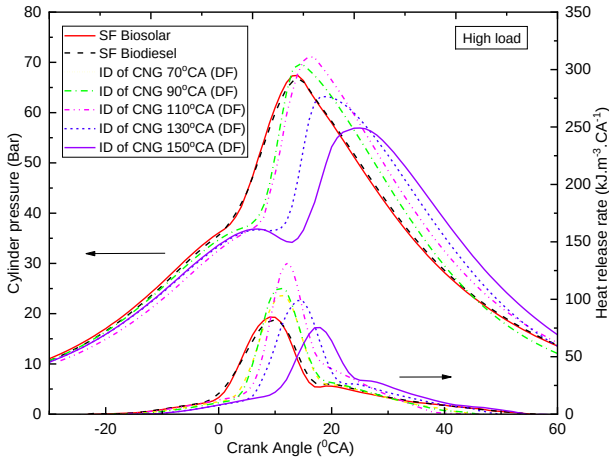

Figure 2. Cylinder pressure and heat release rate at different injection durations of CNG.

Then also with the addition of a lot of biodiesel fuel, the local mixture in the spray area becomes better so that the combustion rate becomes faster. As a result of the increase in combustion temperature, the substitution of CNG fuel can be increased by increasing the injection duration of CNG. By substituting more CNG fuel under high loads, the combustion rate of CNG fuel is faster because the temperature of the CNG fuel during the suction and compression strokes has increased significantly. This phenomenon has also been shown in previous studies, that at high loads, the substitution of CNG fuel can be increased and results in high cylinder pressure [16]–[20].

The heat release rate was also seen to increase significantly when the substitution of CNG fuel was increased by slightly lengthening the duration injection of CNG under high load, this phenomenon was also shown in previous studies [16], [18], [20], [21]. The highest heat release rate was obtained at 110 °CA CNG injection duration with a value of 132.20 kJ/m³.CA. The increase in heat release rate resulted from the diffusion combustion of high CNG fuel because the total amount of CNG fuel burned was more due to the increase in premix from biodiesel fuel, this is indicated by a significant increase in the heat release rate graphic.

Liu et al. [16] explained that the increased release rate was due to the greater amount of CNG burned, as a result of a significant increase in the combustion of pre-blended biodiesel fuel due to more ignition kernels and a wider ignition zone around the combustion chamber due to the increased amount of biodiesel fuel under high load by the governor mechanism to maintain performance and engine speed. Karagöz et al. [20] explained that the rate of heat release in a diesel dual fuel engine increases significantly compared to a conventional diesel engine at full load, but the rate of heat release decreases again if the concentration of CNG fuel is too much.

However, if the injection duration of CNG is too long above 130 °CA to 150 °CA, it will result in a decrease in the rate of heat release. This is due to a decrease in combustion temperature and pressure with the substitution of CNG fuel which is too high, this phenomenon was also shown in previous studies [20], [22].

Then also, by optimizing the duration injection of CNG of 110 °CA, a CNG substitution of 66% was produced. When the substitution value is increased too much through the duration injection of CNG above 130-150 °CA, a decrease in engine performance is found, which is marked by a decrease in cylinder pressure and the rate of heat release. This is because the amount of

CNG fuel is too rich so that the combustion is poor which causes a decrease in the combustion process.

3.2 Evaluation of student knowledge level

After disseminating research results to students by entering the Energy Conversion Machine course on fuel motors. After the dissemination was carried out, a research on the level of understanding of students was carried out using a questionnaire related to dual fuel diesel engine technology material. Figure 3 shows the level of student understanding after dissemination through learning.

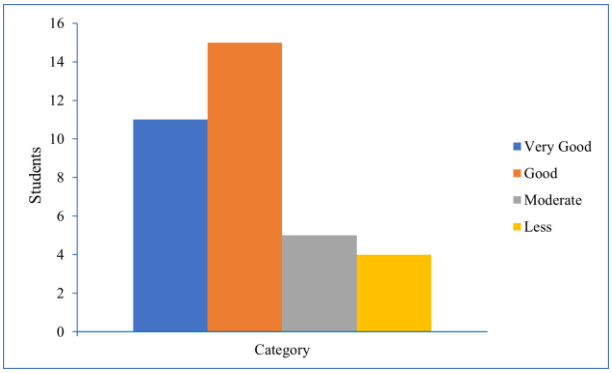

Figure 3. Student understanding level

From the graph it is explained that students who have a level of understanding above are very good and good are 26 students while students with moderate and poor understanding are 9 students. This shows that 74% of students can understand material related to diesel dual fuel engine technology very well and well.

4. CONCLUSSION

After conducting research by optimizing the duration of CNG fuel injection in dual fuel diesel engines under high loads, it can be concluded that the optimal injection duration is obtained at 110 °CA which is characterized by an increase in cylinder pressure and heat release rate. The implication of this research is that the results of the research are disseminated in the learning process in energy conversion engine madrasas so that they can add insight and knowledge to students related to diesel dual fuel engine technology.

AUTHORS' CONTRIBUTIONS

Dori Yuvenda: conceptualization, methodology, results analysis and discussion, writing—original draft, **Randi Purnama Putra:** validation, resources, **Purwantono:** project administration, supervision, **Waskito:** supervision, **Jasman:** supervision. All authors have read and agreed to the published version of the manuscript.

ACKNOWLEDGMENTS

The authors would like to thank the entire research team that has collaborated in producing this work and also The Institute for Research and Community Service, Universitas Negeri Padang, which has funded this research.

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