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Optimizing Low-Load Performance: Investigating Diesel-Hydrogen Dual Fuel Engine Combustion Traits

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ABSTRACT

The current study looked at hydrogen as a fuel for diesel engines running at low load. Because hydrogen has a greater auto ignition temperature than diesel fuel, it cannot be utilized directly in a diesel engine. An alternative method for enrichment or induction is hydrogen. To investigate the combustion characteristics of this dual fuel engine, diesel fuel was converted to hydrogen in a single-cylinder research engine. In order for hydrogen to access the combustion chamber, it had to be added to the intake manifold using a mixer. The engine ran continuously at 2000 rpm with a 10 Nm load. Hydrogen was introduced at flow rates of 21.4, 36.2, and 49.6 liters per minute. Cylinder pressure, recommended efficiency, and specific energy consumption were investigated. At this modest load, the hydrogen enrichment lowered the cylinder's peak pressure. Slower reaction progress variable and reaction combustion rate were shown via open Modelica modeling.

Keywords: Hydrogen; Diesel; Dual fuel; Combustion; Open Modelica.

1. Introduction

It also produces less pollution. Other characteristics of hydrogen, such as its low density, short quenching distance, and low ignition energy, would be difficult to overcome when utilizing it as fuel for internal combustion engines [1] A significant reduction in ignition delay, extremely high peak pressure rates, an increase in smoke, and a deterioration in fuel efficiency were the outcomes of hydrogen induction, especially when its energy share rose over 15% [2,3]. With no EGR, dual fuel operation produced the least amount of smoke and unburned HC. EGR successfully decreased NOx emissions [4]. It was discovered that while NOx emissions sharply decreased with EGR, CO, FSN, and THC increased. In contrast, NOx increases with hydrogen while CO, FSN, and THC emissions decrease. Because of this inverse relationship, it will be possible to tune the mix of hydrogen induction and EGR to reduce both FSN and NOx [5]. The engine's brake thermal efficiency increased when port-injected hydrogen was used, and emissions were reduced even more [6]. Any reduction in emissions, particularly NOx, is probably the result of pressurized hydrogen being injected through the intake valve, which increases turbulent mixing in the cylinder [7]. The amount of published papers in the subject of hydrogen-diesel co-combustion is not as rich as for hydrogen utilized in spark-ignited engines [8–10]., despite increased study on hydrogen combustion in internal combustion engines [11;12]. The work being presented here aims to investigate how hydrogen enrichment affects low-load diesel combustion in a stationary diesel engine. In order to do this, experiments were run to look at how a diesel-hydrogen dual fuel engine burns fuel at different hydrogen flow rates.

2. Open Modelica Modeling and performance evaluation

The combustion process of the diesel-hydrogen dual fuel engine was simulated using Open Modelica. The starting value was defined as the equivalency ratio of 0.203, 0.367, and 0.530 for the hydrogen flow rates of 21.4, 36.2, and 49.6 l/min, respectively.

3. Results and discussion

3.1. Open Modelica analysis of dual fuel combustion

This may be due to the detailed input data, especially for the fuel injection profile. Additionally, a simplification of the injection rate profile was made. The liquid fuel was presumably injected at the same

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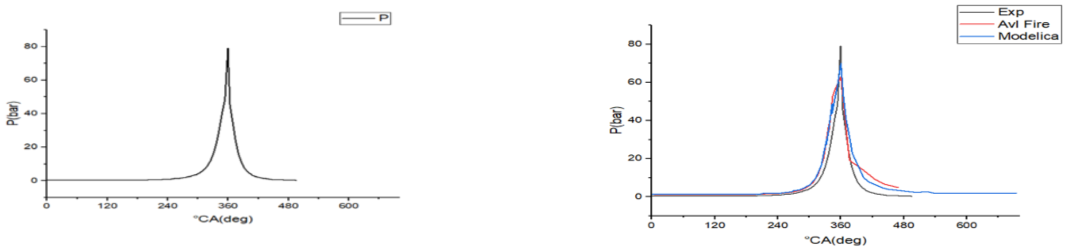
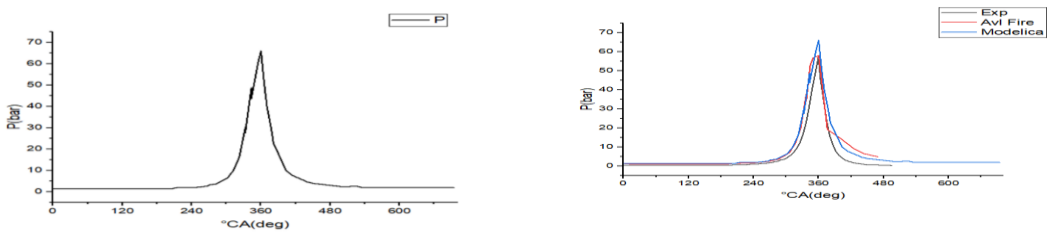
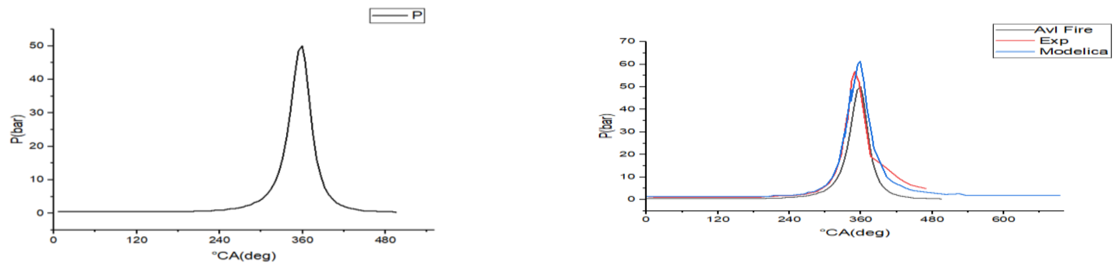
time as the start of injection and end of injection . It has been demonstrated that higher hydrogen enrichment led to a slower reaction rate and a later combustion start.When there was enough diesel fuel to support auto-ignition, combustion began more easily.



(a) H_2 = 21.4 l/min



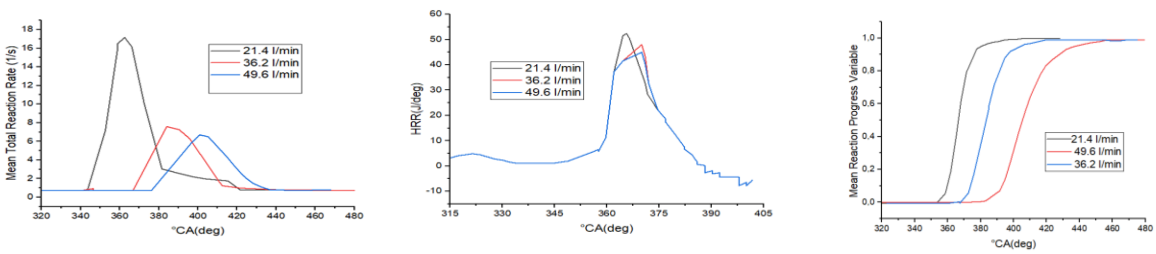
(b) H_2 = 36.2 l/min



(c) H_2 = 49.6 l/min

Figure 1: Comparison between modelisation, simulation and experiment result on cylinder pressure at 2000 rpm

With less hydrogen enrichment, the fuel depletes more quickly, the reaction progress variable is another characteristic that needs to be looked into in order to understand the dual fuel engine's combustion process. 2b illustrates how the amount of diesel fuel used to ignite the premixing of hydrogen with air was decreased, which led to a delayed start of combustion. At a lower hydrogen percentage, a higher fuel depletion rate can be attained. The combustion product began to form early.



(a) (b) (c)

Figure2: (a) Variation of mean total reaction rate with hydrogen enrichment; (b) rate of heat release ;(c) Mean reaction progress variable

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4. Conclusion

Enriching with hydrogen lowered the peak pressure and delayed the beginning of combustion. According to open Modelica modeling, the high percentage of hydrogen enrichment led to a slower rate of reaction progress because of a lower rate of reaction combustion. The advancement of the combustion processes was demonstrated by temperature distributions along the cut plane at the spray axis.

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