

INTISARI

Kebutuhan peningkatan efisiensi dan penurunan emisi pada sektor pembangkit listrik mendorong pengembangan teknologi mesin rendah karbon. Pemanfaatan gas alam cair (*LNG*) sebagai bahan bakar utama, dengan dukungan *co-firing* hidrogen, menjadi salah satu opsi transisi energi yang mulai sering dilakukan. Namun, karakteristik pembakaran mesin *dual fuel* sangat dipengaruhi oleh kondisi operasi, khususnya variasi beban mesin dan rasio udara–bahan bakar aktual dan stoikiometri (*equivalence ratio*), yang berimplikasi langsung terhadap performa dan stabilitas pembakaran. Oleh karena itu, diperlukan kajian yang komprehensif untuk memahami pengaruh variasi beban dan *equivalence ratio* terhadap performa dan emisi *diesel gas engine*.

Penelitian ini menggunakan pendekatan simulasi numerik berbasis *Computational Fluid Dynamics (CFD)* untuk menganalisis performa *diesel gas engine*. Simulasi dilakukan pada variasi beban mesin sebesar 100%, 95%, 85%, dan 75% dengan variasi *equivalence ratio* pada setiap kondisi beban, sementara fraksi mol hidrogen dalam campuran bahan bakar gas dijaga konstan pada 20%. Model numerik dikembangkan untuk merepresentasikan proses aliran, pembentukan campuran, dan pembakaran di dalam silinder, serta divalidasi menggunakan parameter operasi mesin yang merepresentasikan kondisi aktual.

Hasil penelitian menunjukkan bahwa pengaruh variasi beban terhadap karakteristik pembakaran, performa, dan emisi berbeda pada setiap kondisi *equivalence ratio*. Pada *equivalence ratio* sebesar 0,45, peningkatan beban dari 75% menuju 100% menyebabkan peningkatan tekanan puncak, *gross indicated work*, dan efisiensi termal. Namun, pada beban 75% terjadi keterlambatan pembakaran sehingga menyebabkan penurunan performa mesin. Sebaliknya, pada *equivalence ratio* sebesar 0,50, karakteristik pembakaran relatif lebih stabil pada seluruh variasi beban dan menghasilkan kondisi operasi optimum pada beban rendah. Hasil simulasi juga menunjukkan bahwa peningkatan *equivalence ratio* meningkatkan temperatur pembakaran dan emisi NO_x , sedangkan emisi CO cenderung menurun. Secara keseluruhan, kondisi operasi optimum pada *diesel gas engine* LNG–H₂ bersifat bergantung pada beban operasi, dimana kondisi optimum diperoleh pada *equivalence ratio* 0,45 untuk beban 85%–100% dan bergeser menjadi 0,50 pada beban 75%.

Kata kunci: *co-firing* LNG-Hidrogen, *Diesel gas engine*, Simulasi *CFD*, Beban, *Equivalence ratio*

ABSTRACT

The increasing demand for higher efficiency and lower emissions in the power generation sector has driven the development of low-carbon internal combustion engine technologies. The utilization of liquefied natural gas (LNG) as the primary fuel, supported by hydrogen co-firing, has emerged as a promising energy transition option. However, the combustion characteristics of dual fuel diesel–gas engines are influenced by operating conditions, particularly engine load variation and the ratio of the actual air fuel ratio to the stoichiometric air fuel ratio (equivalence ratio), which directly affect engine performance and combustion stability. Therefore, a comprehensive investigation is required to understand the effects of load and AFR variations on the performance and emissions of dual fuel diesel gas engines.

This study employs a numerical simulation approach based on Computational Fluid Dynamics (CFD) to analyze the performance of a dual fuel diesel gas engine of the 18V50DF type. Simulations are conducted at engine load variations of 100%, 95%, 85% and 75%, with different equivalence ratio values applied at each load condition, while the hydrogen molar fraction in the gaseous fuel mixture is maintained constant at 20%. The numerical model is developed to represent in-cylinder flow, mixture formation, and combustion processes, and is validated using operating parameters representative of actual engine conditions.

The results indicate that the effect of engine load variation on combustion characteristics, performance, and emissions differs for each equivalence ratio condition. At an equivalence ratio of 0.45, increasing the engine load from 75% to 100% improved peak pressure, gross indicated work, and thermal efficiency. However, at 75% load, delayed combustion occurred, resulting in reduced engine performance. In contrast, at an equivalence ratio of 0.50, combustion characteristics remained relatively stable across all load conditions, resulting in optimum operation at low load. The simulation results also showed that increasing the equivalence ratio increased combustion temperature and NO_x emissions, while CO emissions tended to decrease. Overall, the optimum operating condition of the LNG–H₂ diesel gas engine was found to be load-dependent, where the optimum equivalence ratio was 0.45 at medium-to-high loads (85%–100%) and shifted to 0.50 at 75% load.

Keywords: *co-firing LNG-hydrogen, Diesel gas engine, CFD simulation, Load, Equivalence ratio*