RINGKASAN

ANALISIS KUALITAS *SYNGAS* PADA PROSES GASIFIKASI *UPDRAFT* MENGGUNAKAN ARANG CANGKANG KELAPA SAWIT DENGAN PENAMBAHAN *SUPERHEATED STEAM*

(Sigi Pegi Ramadhani, 2026, Skripsi, 99 Halaman, 36 Tabel, 31 Gambar)

Indonesia memiliki ketergantungan tinggi terhadap bahan bakar fosil sebesar lebih dari 85% bauran energi primer nasional, sementara realisasi energi baru terbarukan baru mencapai 14,65% dari target 23%. Cangkang kelapa sawit sebagai limbah padat industri kelapa sawit berpotensi dimanfaatkan sebagai bahan baku gasifikasi untuk menghasilkan *syngas*. Penelitian ini bertujuan menganalisis pengaruh variasi laju alir injeksi air terhadap komposisi *syngas*, nilai *Lower Heating Value* (LHV), dan *Cold Gas Efficiency* (CGE) pada proses gasifikasi *updraft* menggunakan arang cangkang kelapa sawit dengan penambahan *superheated steam*. Penelitian dilakukan menggunakan reaktor *updraft* berkapasitas 10 kg dengan bahan baku arang cangkang kelapa sawit hasil karbonisasi pada suhu 500°C selama 3 jam. Variasi laju alir injeksi air sebesar 0, 2, 4, 6, dan 8 ml/menit diinjeksikan langsung ke zona pembakaran reaktor sehingga terkonversi menjadi *superheated steam* secara *in situ*. *Syngas* dianalisis pada dua jalur, yaitu *bypass* dan via *wet scrubber* berbasis larutan NaOH, menggunakan *Multi Gas Detector Analyzer*. Hasil penelitian menunjukkan bahwa peningkatan laju alir injeksi air dari 0 hingga 8 ml/menit meningkatkan kandungan H_2 dari 10,20% menjadi 14,00% (*bypass*) dan dari 11,50% menjadi 15,40% (via *wet scrubber*), serta menurunkan kandungan CO dari 28,40% menjadi 26,50% (*bypass*) akibat dominasi reaksi *water-gas shift*. Nilai LHV *syngas* meningkat dari 5.082,35 menjadi 5.503,30 kJ/Nm³ (*bypass*) dan dari 5.003,74 menjadi 5.823,56 kJ/Nm³ (via *wet scrubber*), seluruhnya melampaui ambang minimum aplikasi mesin pembakaran dalam sebesar 2.500 kJ/Nm³. Nilai CGE menunjukkan tren meningkat hingga laju alir 6 ml/menit dengan nilai optimum 38,78% (*bypass*), kemudian menurun pada laju alir 8 ml/menit akibat pendinginan zona pembakaran yang berlebihan. Kondisi operasi optimum dicapai pada laju alir 6 ml/menit dengan durasi nyala generator terpanjang, yaitu 5 jam 19 menit. Penelitian ini menunjukkan bahwa injeksi air secara *in situ* merupakan dapat meningkatkan kualitas *syngas* dari arang cangkang kelapa sawit sebagai sumber energi terbarukan berbasis limbah perkebunan.

Kata kunci: gasifikasi *updraft*, arang cangkang kelapa sawit, *superheated steam*, *syngas*, *Lower Heating Value* (LHV), *Cold Gas Efficiency* (CGE)

ABSTRACT

**ANALYSIS OF SYNGAS QUALITY
IN THE UPDRAFT GASIFICATION PROCESS
USING PALM KERNEL SHELL CHAR
WITH THE ADDITION OF SUPERHEATED STEAM**

(Sigi Pegi Ramadhani, 2026, Undergraduate Thesis, 99 Pages, 36 Tables, 31 Figures)

Indonesia has a high dependence on fossil fuels, accounting for more than 85% of the national primary energy mix, while the realization of new and renewable energy has only reached 14.65% of the 23% target. Palm kernel shell, as a solid waste product of the palm oil industry, has the potential to be utilized as a gasification feedstock to produce syngas. This study aims to analyze the effect of water injection flow rate variation on syngas composition, Lower Heating Value (LHV), and Cold Gas Efficiency (CGE) in the updraft gasification process using palm kernel shell charcoal with the addition of superheated steam. The research was conducted using a 10 kg capacity updraft reactor with palm kernel shell charcoal feedstock produced through carbonization at 500°C for 3 hours. Water injection flow rate variations of 0, 2, 4, 6, and 8 ml/minute were injected directly into the combustion zone of the reactor, converting in situ into superheated steam. Syngas was analyzed through two pathways, namely bypass and via a NaOH-based wet scrubber, using a Multi Gas Detector Analyzer. The results showed that increasing the water injection flow rate from 0 to 8 ml/minute increased the H_2 content from 10.20% to 14.00% (bypass) and from 11.50% to 15.40% (via wet scrubber), and decreased the CO content from 28.40% to 26.50% (bypass) due to the dominance of the water-gas shift reaction. The syngas LHV value increased from 5,082.35 to 5,503.30 kJ/Nm³ (bypass) and from 5,003.74 to 5,823.56 kJ/Nm³ (via wet scrubber), all exceeding the minimum threshold for internal combustion engine applications of 2,500 kJ/Nm³. The CGE value showed an increasing trend up to a flow rate of 6 ml/minute, with an optimum value of 38.78% (bypass), then decreased at a flow rate of 8 ml/minute due to excessive cooling of the combustion zone. The optimum operating condition was achieved at a flow rate of 6 ml/minute, with the longest generator burn duration of 5 hours 19 minutes. This study demonstrates that in situ water injection can improve the quality of syngas derived from palm kernel shell charcoal as a renewable energy source based on plantation waste.

Keywords: updraft gasification, palm kernel shell charcoal, superheated steam, syngas, Lower Heating Value (LHV), Cold Gas Efficiency (CGE)