PERANCANGAN DAN ANALISIS SISTEM KONTROL PENGUAPAN PARSIAL PADA SIKLUS RANKINE ORGANIK BERBASIS METODE PID

oleh

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INTISARI

Siklus Rankine Organik dengan penguapan parsial (PE-ORC) menawarkan efisien yang lebih tinggi dibandingkan ORC konvensional dalam hal pemanfaatan panas buang. Namun, operasi kerjanya (kualitas uap) tidak stabil akibat sifat sumber panas yang fluktuatif dan intermiten. Penelitian ini bertujuan merancang dan menganalisis sistem kontrol PID untuk menjaga stabilitas kualitas uap pada sistem PE-ORC.

Model termodinamika keadaan tunak PE-ORC dibangun di DWSIM menggunakan penukar panas tipe *shell-and-tube* yang didesain dengan metode Tinker dan $\epsilon - NTU$. Sistem kontrol PID dibangun pada model tersebut, dan penyetelan penguatan PID dilakukan dengan metode Ziegler-Nichols (dan lanjutan). Simulasi sistem kontrol dilakukan dengan memodelkan sumber panas buangan berfluktuasi.

Model termodinamika keadaan tunak PE-ORC yang dibangun menghasilkan $x_1 = 0,75$, $\dot{W}_{keluar,net} = 142,4$ kW, dan $\eta_{siklus} = 15,16\%$. Perancangan penukar panas mampu mendukung tercapainya model tersebut. Pada struktur sistem kontrol, x_1 dikontrol dengan manipulasi $\dot{m}_{hs,in}$ dan manipulasi p_4. Penguatan PID hasil penyetelan bernilai $K_P = 0,425$, $K_I = 0,0125$, dan $K_D = 0,6$. Hasil simulasi sistem kontrol PID pada PE-ORC dengan adanya fluktuasi menunjukkan pengontrol PID mampu menjaga x_1 tetap berada di nilai targetnya $(0,8)$, dengan metrik statistiknya berupa rata-rata bernilai $0,8$, deviasi standar bernilai $0,011$, dan MAE bernilai $0,08$.

Kata kunci: PE-ORC, PID, Penyetelan PID

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DESIGN AND ANALYSIS OF PARTIAL EVAPORATION CONTROL SYSTEM IN ORGANIC RANKINE CYCLE BASED ON PID METHOD

by

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ABSTRACT

The Partially Evaporated Organic Rankine Cycle (PE-ORC) offers higher efficiency compared to the conventional ORC in terms of waste heat utilization. However, its operation (vapor quality) is unstable due to the fluctuating and intermittent nature of the heat source. This research aims to design and analyze a PID control system to maintain the stability of the vapor quality in a PE-ORC system.

A steady-state thermodynamic model of the PE-ORC was developed in DWSIM, featuring shell-and-tube heat exchangers designed using the Tinker and $\epsilon - NTU$ methods. A PID control system was then implemented on this model, and the controller gains were tuned using the Ziegler-Nichols method (with fine-tuning). The control system simulation was performed by modeling a fluctuating waste heat source.

The developed steady-state thermodynamic model of the PE-ORC yields $x_1 = 0.75$, $\dot{W}_{out,net} = 142.4$ kW, and $\eta_{cycle} = 15.16\%$. The heat exchanger design was capable of supporting this model. In the control system structure, x_1 is controlled by manipulating $\dot{m}_{hs,in}$ and p_4. The tuned PID gains were determined to be $K_P = 0.425$, $K_I = 0.0125$, and $K_D = 0.6$. The simulation results of the PID control system under fluctuating conditions show that the controller is able to maintain x_1 at its target value (0.8), with statistical metrics showing an average of 0.8, a standard deviation of 0.011, and an MAE of 0.08.

Keywords: PE-ORC, PID, PID tuning

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