

INTISARI

PERANCANGAN DAN SIMULASI SISTEM KENDALI *CASCADE LEVEL CAVITY* DAN DAYA LISTRIK MOTOR *CONE CRUSHER* PADA PROSES *SECONDARY CRUSHING* DI PT AGINCOURT RESOURCES DENGAN PENGENDALI *PROPORTIONAL-INTEGRAL-DERIVATIVE (PID)*

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Penelitian ini merancang dan mengevaluasi sistem kendali *cascade* berbasis pengendali *Proportional-Integral-Derivative (PID)* untuk mengendalikan *level* material dalam *cavity* dan daya listrik motor *cone crusher* pada proses *secondary crushing* di PT Agincourt Resources, serta membandingkan kinerjanya dengan sistem kendali *single-loop*. Model dinamika sistem diperoleh melalui pendekatan *grey-box modeling* yang menggabungkan pemahaman fisik proses dengan estimasi parameter menggunakan metode *Least Squares* berdasarkan data historis proses. Model yang diperoleh dinyatakan valid berdasarkan evaluasi kuantitatif menggunakan kriteria MSE, RMSE, dan *fit percentage*. Parameter pengendali PI ditentukan menggunakan metode penalaan *Internal Model Control (IMC)*, menghasilkan parameter terpilih untuk sistem kendali *single-loop* dengan nilai $K_p = 55,626$ dan $K_i = 0,551$, *cascade inner loop* dengan nilai $K_p = 0,881$ dan $K_i = 0,061$, serta *cascade outer loop* dengan nilai $K_p = 195,329$ dan $K_i = 2,083$, dengan pemilihan τ_c didasarkan pada kriteria tidak adanya *overshoot*. Hasil penelitian melalui simulasi MATLAB Simulink menunjukkan bahwa sistem kendali *cascade* unggul dibandingkan sistem kendali *single-loop* pada aspek kinerja *setpoint tracking* maupun *disturbance rejection*. Dari segi *setpoint tracking*, sistem kendali *cascade* menghasilkan *rise time* 37,4 s dan *settling time* 172,2 s, lebih cepat dibandingkan *single-loop* dengan *rise time* 58,4 s dan *settling time* 313,2 s, dengan *overshoot* 0% dan *steady-state error* $\approx 0\%$ pada keduanya. Hal ini menunjukkan peningkatan performa respons pada sistem kendali *cascade* sebesar 35,96% lebih cepat untuk *rise time* dan 45,02% lebih cepat untuk *settling time* dibandingkan sistem kendali *single-loop*. Dari segi *disturbance rejection*, sistem kendali *cascade* menunjukkan keunggulan yang jauh lebih signifikan dengan deviasi *level* maksimum hanya -0,005 m dan *recovery time* 0 s, dibandingkan sistem kendali *single-loop* yang menghasilkan deviasi *level* maksimum -0,022 m dan *recovery time* 220,4 s. Peningkatan performa pada aspek *disturbance rejection* ini mencapai 76,83% pada pengurangan deviasi *level* maksimum dan 100% lebih cepat pada *recovery time*.

Kata kunci: *cascade control, PID controller, grey-box modeling, Internal Model Control (IMC), cone crusher, secondary crushing*

ABSTRACT

DESIGN AND SIMULATION OF A CASCADE CONTROL SYSTEM FOR CAVITY LEVEL AND MOTOR ELECTRIC POWER OF A CONE CRUSHER IN THE SECONDARY CRUSHING PROCESS AT PT AGINCOURT RESOURCES USING A PROPORTIONAL-INTEGRAL-DERIVATIVE (PID) CONTROLLER

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This study designs and evaluates a cascade control system based on Proportional–Integral–Derivative (PID) controllers to regulate material level in the cavity and motor power of a cone crusher in the secondary crushing process at PT Agincourt Resources, and compares its performance against a single-loop control system. The system dynamics model was obtained through a grey-box modeling approach that combines physical process understanding with parameter estimation using the Least Squares method based on historical process data. The resulting model was declared valid based on quantitative evaluation using MSE, RMSE, and fit percentage criteria. Controller parameters were determined using the Internal Model Control (IMC) tuning method, yielding selected PI parameters for the single-loop control system of $K_p = 55.626$ and $K_i = 0.551$, for the cascade inner loop of $K_p = 0.881$ and $K_i = 0.061$, and for the cascade outer loop of $K_p = 195.329$ and $K_i = 2.083$, with the selection of τ_c based on the criterion of zero overshoot. Simulation results obtained via MATLAB Simulink demonstrate that the cascade control system outperforms the single-loop control system in both setpoint tracking and disturbance rejection performance. In terms of setpoint tracking, the cascade control system achieved a rise time of 37.4 s and a settling time of 172.2 s, compared to the single-loop system's rise time of 58.4 s and settling time of 313.2 s, with both systems exhibiting 0% overshoot and approximately 0% steady-state error. This represents a performance improvement of 35.96% in rise time and 45.02% in settling time for the cascade control system relative to the single-loop system. In terms of disturbance rejection, the cascade control system demonstrated a substantially more significant advantage, with a maximum level deviation of only -0.005 m and a recovery time of 0 s, compared to the single-loop system's maximum level deviation of -0.022 m and recovery time of 220.4 s. The performance improvement in disturbance rejection reached 76.83% in maximum level deviation reduction and 100% in recovery time.

Keyword: *cascade control, PID controller, grey-box modeling, Internal Model Control (IMC), cone crusher, secondary crushing*