

Rancang Bangun Sistem Optimasi Konsumsi Batubara pada Industri Feronikel dengan Algoritma R-NSGA-II = Design and Development of Coal Consumption Optimization System in Ferronickel Industry with R-NSGA-II Algorithm

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Abstrak

Penelitian ini mengoptimalkan konsumsi batubara dalam proses produksi nikel dengan mesin pirometalurgi Rotary Kiln Electric Furnace (RKEF) untuk mengatasi tantangan tingginya biaya operasional dan emisi lingkungan. Tujuan penelitian adalah mengembangkan kerangka kerja optimasi untuk meminimalkan konsumsi batubara total sambil mempertahankan kualitas produk dan target operasional. Kerangka kerja optimasi dikembangkan dengan algoritma optimasi dan dibantu oleh model surrogate yang telah dilatih dari data operasional historis mesin. Optimasi yang dilakukan meliputi empat pendekatan: (1) Sequential Least Squares Programming (SLSQP) objektif tunggal sebagai baseline, (2) R-NSGA-II multiobjektif, (3) optimasi sekuensial dengan SLSQP, dan (4) optimasi sekuensial dengan R-NSGA-II. Eksperimen pada sampel data uji menunjukkan R-NSGA-II objektif tunggal memberikan kinerja terbaik dengan penghematan konsumsi batubara bahan bakar 32.8% dan batubara reduktor 64.1%, sambil meningkatkan kadar nikel 18.3% dan memenuhi 100% batasan operasional. R-NSGA-II sekuensial mencapai penghematan signifikan 22.5% bahan bakar dan 19.2% reduktor dengan kelayakan sempurna, SLSQP objektif tunggal menghasilkan penghematan konservatif 21.0% bahan bakar dengan kelayakan 100%, sedangkan SLSQP sekuensial menunjukkan penghematan minimal 0.10% bahan bakar dan 5.01% reduktor namun tetap mempertahankan kelayakan sempurna. Secara keseluruhan, penelitian ini membuktikan bahwa integrasi model surrogate machine learning dengan algoritma optimasi multi-objektif R-NSGA-II dapat memberikan solusi efektif untuk mengoptimalkan efisiensi energi dan profitabilitas dalam industri pengolahan nikel.

.....This research optimizes coal consumption in nickel production using the Rotary Kiln Electric Furnace (RKEF) pyrometallurgical route to address challenges from high operational costs and environmental emissions. The research objective is to develop an optimization framework to minimize total coal consumption while maintaining product quality and operational targets. The optimization framework was developed using optimization algorithms assisted by surrogate models trained from historical operational machine data. The optimization conducted includes four approaches: (1) Sequential Least Squares Programming (SLSQP) single-objective as baseline, (2) R-NSGA-II multi-objective, (3) sequential optimization with SLSQP, and (4) sequential optimization with R-NSGA-II. Experiments on test data samples demonstrate that single-objective R-NSGA-II achieves superior performance with 32.8% fuel coal savings and 64.1% reductor coal savings while simultaneously increasing nickel grade by 18.3% and meeting 100% operational constraints. Sequential R-NSGA-II achieves significant savings of 22.5% fuel and 19.2% reductor with perfect feasibility, single-objective SLSQP provides conservative savings of 21.0% fuel with 100% feasibility, while sequential SLSQP shows minimal savings of 0.10% fuel and 5.01% reductor while maintaining perfect feasibility. Overall, this research demonstrates that the integration of surrogate machine learning models with multi-objective optimization algorithm R-NSGA-II can provide effective solutions for optimizing energy efficiency and profitability in the nickel processing industry.