ENERGY AND EXERGY EFFICIENT GRATE CLINKER COOLING SYSTEM

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ABSTRACT

The cement production ranks among the most energy intensive industrial processes, for which energy expenditure alone typically accounts for 30-40% of the production cost. It also contributes towards atmospheric pollution via the emission of major air pollutants such as nitrogen oxides, carbon monoxide and particulate matter, and greenhouse gas carbon dioxide. The goal of this study is to improve the efficiencies of a grate clinker cooling system through the optimization of its operational parameters, which consequently reduces the cost of thermal energy and the emissions of air pollutants and greenhouse gas. The study uses two approaches, i.e. the conventional energy analysis as well as the exergy analysis of the system's operational parameters, i.e. mass flow rate of cooling air, cooling air temperature, mass flow rate of clinker and grate speed, through simulated air and clinker temperature profiles. It was found that the energy efficiency and the energy recovery efficiency can be increased by an average of 2.3% and 1.6% respectively, while the exergy efficiency and the exergy recovery efficiency by an average of 2.5% and 1.9% respectively, for every 5% optimization of the operational parameters of the system. The exhaust heat recovery alone contributes to 21.5% of energy recovery efficiency and 9.4% of exergy recovery efficiency. The cost benefit analyses suggest that decreasing the mass flow rate of clinker is the most beneficial way to improve the system's efficiencies, with USD 0.196 per tonne of clinker of cost saving, 6.1 months of payback period, an investment present value of USD 483,141.00, and a cost of USD 0.41/GJ energy conserved. Results from the emission reduction analysis also prove that decreasing the mass flow rate of clinker contributes the most towards emission reduction per unit clinker produced, i.e. 0.037 kg of NO_x/tonne, 0.029 of CO/tonne, 0.002 kg of PM/tonne, and 4.393 kg of CO_2/tonne.

ABSTRAK

Proses pengeluaran semen merupakan di antara proses yang paling banyak menggunakan tenaga, di mana penggunaan tenaga sahaja merangkumi 30-40% kos pengeluaran. Proses tersebut juga menyumbang kepada pencemaran udara melalui pembebasan gas-gas pencemar seperti oksida-oksida nitrogen, karbon monoksida dan habuk, serta gas rumah hijau karbon dioksida. Tujuan kajian ini adalah untuk meningkatkan efisiensi-efisisensi penyejuk klinker jenis memayang melalui pengoptimalan parameter-parameter operasinya. Ianya akan menyumbang kepada pengurangan kos tenaga haba dan pembebasan gas-gas pencemar serta gas rumah hijau. Kajian ini menggunakan dua kaedah, iaitu analisis tenaga dan analisis eksergi bagi parameter-parameter operasi yang terpilih seperti kadar jirim udara penyejuk, suhu udara penyejuk, kadar jirim klinker, dan kelajuan memayang, berlatarkan profil suhu udara dan klinker yang disimulasikan. Kajian mendapati efisiensi-efisiensi prinsip pertama dapat ditingkatkan sebanyak 2.3% dan 1.6% secara purata, manakala efisiensi-efisienci prinsip kedua sistem sebanyak 2.5% dan 1.9% secara purata, bagi setiap 5% pengoptimalan parameter-parameter operasi sistem. Penggunaan kembali tenaga haba yang terkandung di dalam udara ekzos secara puratanya menyumbangkan 21.5% dan 9.4% daripada effisiensi-efisiensi prinsip pertama dan efisiensi-efisiensi prinsip kedua sistem. Analisis-analisis kos menunjukkan bahawa pengurangan kadar jirim klinker merupakan kaedah terbaik bagi meningkatkan efisiensi-efisiensi sistem, dengan pengurangan kos sebanyak USD 0.196 setiap ton klinker, 6.1 bulan bayaran balik pelaburan, USD 483,141.00 nilai pelaburan semasa, dan USD 0.41/GJ kos tenaga yang diselamatkan. Analisis pengurangan pembebasan gas pencemar juga menyarankan pengoptimalan kadar jirim klinker dapat mengurangkan 0.037 kg NO_x, 0.029 kg CO, 0.002 kg PM, dan 4.393 kg CO_2 bagi setiap ton klinker dihasilkan.

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Symbols/ Abbreviation	Meaning
A	Annual Net Cash Flow
ACC	Annualized Capital Cost
C	Specific Heat
CCE	Cost of Conserved Energy
ck	Clinker
cmh	Cubic Meter per Hour
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CRF	Capital Recovery Factor
CS	Cost Saving
°C	Degree Celcius
D_f	Specific Drive Force of Cooler
d	Discount Factor
EM	Emission
EC	Energy Cost
ES	Energy Saving
$\dot{E}$	Rate of Energy
$\dot{E}x$	Rate of Exergy
$\bar{e}$	Specific Exergy
F	Force
G_a	Grate Surface Area
IC	Incremental Cost
IIC	Initial Investment Cost
$\dot{I}$	Rate of Irreversibility
kg	Kilogram

kN	Kilo Newton
kWh	Kilowatt Hour
L_m	Life Span of Upgrade
lit	Liter
mm	Millimeter
m^2	Square Meter
m^3	Cubic Meter
$\dot{m}$	Mass Flow Rate
mbar	Millibar
MJ	Mega Joule
N	Strokes per Minute
No.	Number
NO_x	Nitrogen Oxides
P	Pressure
P	Power
PE	Percentage of Electricity
PJ	Petajoule
PM	Particulate Matter
PV	Present Value
$\dot{Q}$	Rate of Heat
S	Stroke Length
SPP	Simple Payback Period
T	Torque
T	Temperature
Tg	Teragram
ton	Tonne
USD	United States Dollars
VSD	Variable Speed Drive

$\dot{W}$	Rate of Work
η	Efficiency
ψ	Flow Exergy
π	Phi
Σ	Summation