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Waste heat availability in the raw meal department of a cement plant

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ABSTRACT

The main aim of this study was to determine the available heat in the cement kiln exhaust gas subject to different process conditions. A Norwegian cement plant producing about 1.3 million tons of cement per year was used as a case study. A mass and energy balance was made for the raw meal department, and process data available from the plant process database as well as manually measured gas flow rates were used to calculate the available heat. The available heat can be utilized by a combination of low pressure (LP) steam generation and hot water generation. It was found that waste heat is 1.5–4.2 MW for LP steam generation and 2.2–5.8 MW for hot water generation. The variation in available heat is due to different raw meal types being produced, requiring different gas inlet temperatures to raw meal mill. In cases when no raw meal is produced (in maintenance shutdown periods), all the gas will bypass the mill, and approximately 20 MW of LP steam and 6 MW of hot water can be generated. The heat loss from the system was estimated based on measurements, and the fan power inputs were calculated. Both were found to be negligible compared to the available heat. Furthermore, the total false air coming into the system was estimated as 40–50% of the total gas flow rate going out from the raw meal department.

Nomenclature

Abbreviations

A	Atmospheric air
BP	Bypass
CS	Coarse separator
F	Gas cleaning equipment (Electro-static precipitator and Bag filter)
FF	Filter fan
FSA	Full screen analyzer
G	Gas
GS	Gas separation point
HGF	Hot gas fan
LP	Low-pressure (steam)
M	AFM motor
MF	Main fan
RM	Raw material

Roman Symbols

A_{sur}	Surface area of the pipelines and equipment $[m^2]$
$C_{Dust,\ in}$	Concentration of dust in the inlet gas stream coming into the raw meal department $[\frac{g}{Nm^3}]$

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$C_{p,A}(T)$ Specific heat capacity of the atmospheric air[1] $\left[\frac{J}{kg\cdot K}\right]$
$C_{p,G}(T)$ Specific heat capacity of the gas1 $\left[\frac{J}{kg\cdot K}\right]$
$C_{p,RM}(T)$ Specific heat capacity of the raw materials1 $\left[\frac{J}{kg\cdot K}\right]$
D Diameters of the circular gas pipelines $[m]$
$Dust_{AFM,\ in}$ Mass flow rate of dust in the gas stream which is sent to the aero-fall mill (AFM) $\left[\frac{kg}{s}\right]$
$Dust_{AFM,\ out}$ Mass flow rate of dust of the gas stream that coming out from the cyclone system $\left[\frac{kg}{s}\right]$
$Dust_{BP}$ Mass flow rate of dust of the gas stream that going with the bypass gas stream $\left[\frac{kg}{s}\right]$
$Dust_{F,\ in}$ Mass flow rate of dust of the gas stream which is sent to the ESP (BF) $\left[\frac{kg}{s}\right]$
$Dust_{in}$ Mass flow rate of dust in the inlet gas stream coming into the raw meal department $\left[\frac{kg}{s}\right]$
$Dust_{out}$ Mass flow rate of dust of the gas stream which is going out from the raw meal department $\left[\frac{kg}{s}\right]$
$h_s(T)$ Total specific enthalpy of steam $\left[\frac{MJ}{kg}\right]$
L Latent heat of evaporation of water $\left[\frac{J}{kg}\right]$
M_{wA} Molecular weight of atmospheric air $\left[\frac{kg}{mol}\right]$
M_{wG} Molecular weight of gas $\left[\frac{kg}{mol}\right]$
M_{wH_2O} Molecular weight of moisture (water) $\left[\frac{kg}{mol}\right]$
$\dot{m}_{A,\ AFM in}$ Mass flow rate of the false atmospheric air stream coming into the AFM via the raw material entrance opening $\left[\frac{kg}{s}\right]$
$\dot{m}_{A,\ F in}$ Mass flow rate of the false atmospheric air stream coming into the BF and ESP $\left[\frac{kg}{s}\right]$
$\dot{m}_{BF,\ out}$ Mass flow rate of filtered raw meal powder that coming out from the BF $\left[\frac{kg}{s}\right]$
$\dot{m}_{CS,out}$ Total mass flow rate of the crushed raw meal powder that coming out from the coarse separator $\left[\frac{kg}{s}\right]$
$\dot{m}_{Cyclone,\ out}$ Total mass flow rate of the crushed raw meal powder that coming out from the cyclone system $\left[\frac{kg}{s}\right]$
$\dot{m}_{ESP,\ out}$ Mass flow rate of filtered raw meal powder that coming out from the ESP
$\dot{m}_{G,\ AFM in}$ Mass flow rate of the gas stream which is sent to the AFM[2] $\left[\frac{kg}{s}\right]$
$\dot{m}_{G,\ AFM out}$ Mass flow rate of the gas stream coming out from AFM, coarse separator, and the cyclone system[2] $\left[\frac{kg}{s}\right]$
$\dot{m}_{G,\ BP}$ Mass flow rate of the gas stream which is bypassed the raw meal department[2] $\left[\frac{kg}{s}\right]$
$\dot{m}_{G,\ F,\ in}$ Mass flow rate of the mixed gas stream which is sent to the ESP and BF (bypass gas stream + gas stream coming from the raw meal department) [2] $\left[\frac{kg}{s}\right]$
$\dot{m}_{G,\ in}$ Mass flow rate of the gas stream coming into the raw meal department[2] $\left[\frac{kg}{s}\right]$
$\dot{m}_{G,\ out}$ Mass flow rate of the gas stream which is coming out from the ESP and BF and released to the atmosphere[2] $\left[\frac{kg}{s}\right]$
$\dot{m}_{H_2O}$ Mass flow rate of hot water generated $\left[\frac{kg}{s}\right]$
$\dot{m}_{H_2O,\ in}$ Water/moisture mass flow rate of the gas stream which is coming into the raw meal department $\left[\frac{kg}{s}\right]$
$\dot{m}_{RM,\ in}$ Total raw material mass flow rate coming into the AFM (limestone + additives) – Defined as moisture content inclusive $\left[\frac{kg}{s}\right]$
$\dot{m}_{steam}$ Mass flow rate of LP steam generated $\left[\frac{kg}{s}\right]$
P Pressure in the control volume $[Pa]$
P_{BP} Gauge pressure inside the bypass gas stream $[mbar]$
P_{FF} Power input from the filter fan $[kW]$
P_{HGF} Power input from the hot gas fan $[kW]$
P_M Motor power input to the AFM $[MW]$
P_{MF} Power input from the main fan $[kW]$
P_N Normal gas pressure $[Pa]$
Q Available heat $[MW]$
Q_{HW} Available heat for hot water generation $[MW]$
Q_{LP} Available heat for LP steam generation $[MW]$
$Q_{loss,\ AFM}$ Heat loss at the AFM [W]
$Q_{loss,\ AFM to Cyclones}$ Heat loss at the ducts from AFM to cyclone system including heat losses from the surfaces of coarse separator and cyclones [W]
$Q_{loss,\ after Cyclones}$ Heat loss at the ducts going out from the cyclone system along with the heat loss from the main fan [W]
$Q_{loss,\ before AFM}$ Heat loss of the gas stream from the ducts before entering to the AFM [W]
$Q_{loss,\ bypass duct}$ Heat loss at the bypass duct [W]
$Q_{loss,\ ESP\&BF}$ Heat loss from the surfaces of ESP and BF [W]
$Q_{loss,\ inlet duct}$ Heat loss at the inlet gas duct and hot gas fan [W]
$Q_{loss,\ mixed gas duct}$ Heat loss at the duct after the bypass and gas stream coming from the cyclone mixed [W]
$T_{A,\ in}$ Atmospheric air temperature $[°C]$
$T_{G,\ AFM in}$ Temperature of the gas stream which is sent to the AFM $[°C]$
$T_{G,\ AFM out}$ Temperature of the gas stream coming out from AFM, coarse separator, and the cyclone system $[°C]$
$T_{G,\ BP}$ Temperature of the gas stream which is bypassed the raw meal department $[°C]$
$T_{G,\ F,\ in}$ Temperature of the mixed gas stream which is sent to the ESP and BF (bypass gas stream + gas stream coming from the

1 T indicates that the parameter is a function of temperature.
2 The flow rate includes the dust suspended in the gas.