FINAL DRAFT

HT2005-72799

HEAT TRANSFER AND COMPUTATIONAL SIMULATIONS ON THE DRYING PROCESS OF A KILN

Almon Chai
Faculty of Engineering, Universiti
Malaysia Sarawak, 94300 Kota
Samarahan, Sarawak, Malaysia
calmon@pgfeng.unimas.my

Andrew Rigit
Faculty of Engineering, Universiti
Malaysia Sarawak, 94300 Kota
Samarahan, Sarawak, Malaysia
arigit@feng.unimas.my

Ha How Ung
Swinburne University of
Technology (Sarawak Campus),
Kompleks Negeri, Jalan Simpang
Tiga, 93576 Kuching, Sarawak,
Malaysia
hha@swinburne.edu.my

ABSTRACT

In this paper, the analytical and computational results are presented for a large-scale ceramic-tiles drying kiln. A lumped-parameter model was initially derived for the drying process of the kiln. This has led to the development of mathematical models for the energy conservation and convective heat and mass transfer drying process. Diffusion on the boundary layers of the tiles was also derived based on the basis of moisture isotherm, drying curve and different temperature profiles. This also takes into consideration the internal moisture transportation. The developed partial differential equations were discretized using the central-difference approximation method, which were further verified by a computational fluid-dynamics solver and the Gauss-Siedel iterative method. The modelling and simulations performed on the partial differential equations give possible auxiliary energy conservation and improvement on the drying process of the kiln.

INTRODUCTION

Material drying is an energy-intensive operation in the ceramic-tiles manufacturing industry. Understanding of the drying phenomena and development of the mathematical models can lead to improvement on the drying operation and efficiency. To achieve this, the kiln of a large-scale ceramic-tiles drying facility was analyzed. The kiln consumes liquid-petroleum gas and produces combustion air-flow at an average of 900°C. The drying process was further studied through computational fluid-dynamics solver, where the obtained results showed temperature distribution and air-flow velocity magnitude within the kiln. This can also aid in the improvement of the process, such as identification of kiln sections where possible retrofit of heat-retention systems can be installed in order to retain and recycle the exhausted heat.

NOMENCLATURE

ϕ	moisture content in the combustion air-flow phase
T	temperature of the air-flow phase
v	linear velocity combustion air-flow
l	the Cartesian co-ordinate locality
t	time.
C	heat capacity of the combustion air-flow
ρ	linear density
R	drying rate
U	heat transfer coefficient
V	volume per unit length (free for air flow)
λ	heat vaporization of water content within the tile
k	thermal conductivity
h	enthalpy of both differential element and internal moisture content
K_{eff}	efficient thermal conductivity efficient

Subscript

g	combustion air-flow with gas mixture
s	ceramic-tile
w	tile with moisture content
v	volumetric
f	formation taking place during heat vapourization of tile moisture content
s,w	differential element with internal moisture content

DRYING PHENOMENA

Tile-drying is a process where the unbound and/or bound volatile liquid is removed from the tiles via evaporation. When the tile dries, two simultaneous fundamental processes occur. Heat is transferred to the tile from the surrounding medium within the kiln, most commonly air with certain mixture of gas. Moisture is transferred as a liquid or vapour within the material and as a vapour from its boundary surface. The conventional