AN ASSESSMENT OF THE THERMO-PHYSICAL PROPERTIES OF A GR
MODIFIED KENYAN KAOLINITE REFRACTORY

By

KIMANI JOHN NJOROGE
I84/8125/90

A THESIS SUBMITTED IN FULFILLMENT OF THE REQUIREMENT

OF THE DEGREE OF

DOCTOR OF PHILOSOPHY

IN THE DEPARTMENT OF PHYSICS, AT THE UNIVERSITY OF NAIROBI.

DEPARTMENT OF PHYSICS,

UNIVERSITY OF NAIROBI,

P.O. BOX 30197,

NAIROBI,

KENYA.

DECLARATION

This work is an original thesis submitted for the Degree of Doctor of Philosophy in Physics at the University of Nairobi and has not been submitted before at any other institution for assessment.

KIMANI JOHN NJOROGE

BSc (Hons) Phys., PGDE, MSc Phys. (NRB).

Sign..................

This thesis is submitted with my approval as University Supervisor:

PROF. BERNARD O.C. ADUDA,

DEPARTMENT OF PHYSICS,

UNIVERSITY OF NAIROBI,

P.O. BOX 30197,

NAIROBI,

KENYA.

Sign..................

ABSTRACT

This study has investigated the effect of the addition of grog, which is a pre fired material, on the thermo-physical properties and on the performance of a kaolinite clay based refractory material as a thermal insulator. Also assessed was a compromise between the improved thermal insulation and the decreased strength.

The kaolinite clay refractory material has been characterized in terms of the chemical composition, particle size distribution of the raw materials, Young's modulus, specific heat capacity, drying contraction of the green samples, bulk density, apparent porosity, water absorption and microstructure. Mechanical testing to assess the strengths by measuring the modulus of rapture(MOR) was also performed, which also enabled the performance of the Weibull analysis and the calculation of the Weibull modulus. Thermal conductivity analysis was undertaken to assess the heat insulation abilities. Thermal shock analysis was conducted to determine the thermal stresses the material may withstand. Thermal fatigue analysis was done to study the growth of existing cracks, while the assessment of the stress intensity factor enabled us to evaluate the toughness of the samples.

The thermal conductivity values were observed to increase with temperature for samples prepared without mixing with grog as confirmed by theoretical calculations using both the Zumbrunnen et al and the Litovsky et al models. The rate of increase of the thermal conductivity values was observed to decrease with the increase of the percentage of the introduced grog. For samples prepared by mixing with 50% grog, a slight decrease of the thermal conductivity values with temperature was observed.

The critical thermal severity the samples could withstand were also observed to improve with addition of grog to the kaolinite clay raw material. Samples prepared without mixing with grog were observed to withstand a thermal shock severity of about $480^{o}C$. This critical value increased to about $500^{o}C$ with the addition of 50% grog.

The R-parameters for the refractory samples were also observed to improve when the samples were prepared by mixing with grog. The values obtained for R, R', R''' and R'''' for samples without grog were: $721.6K$, $829.8Wm^{-1}$, $3.7X10^{-6}Pa$ and $3.3X10^{-5}N^2m^{-3}$ respectively, while for samples with 50% grog the values were; $743.5K$, $835.7Wm^{-1}$, $3.9X10^{-6}Pa$ and $3.5X10^{-5}N^2m^{-3}$ respectively.

The fatigue life, which is the number of thermal cycles N the material can go through before developing catastrophic cracks was studied by thermal fatigue analysis measurements. Values measured for the slow crack growth parameter n and the Weibull modulus m, showed improvement on crack growth resistance with introduction of grog to the refractory material. For samples prepared without mixing with grog, values obtained for m and n were 29.5 and 19.5 respectively. For samples prepared by mixing with 50% grog, the values for m and n were 30.5 and 29.5 respectively.

The critical stress intensity factor K_{Ic} values measured for samples without and with 50% grog also indicated some improvement on the toughness of the refractories on addition of grog to the material. The values ranged between $1.45MPam^{1/2}$ and $2.3MPam^{1/2}$ for firing temperatures between 600^oC and 1250^oC for samples without grog. For samples with 50% grog in the same firing temperature range, the K_{Ic} values ranged between $1.6MPam^{1/2}$ and $2.6MPam^{1/2}$.

In all these cases, the addition of grog was observed to improve the properties of the refractory material. There was improved toughness, thermal shock resistance, crack growth resistance, rate of increase of thermal conductivity with temperature and improved thermal fatigue resistance.