# EXPERIMENTAL EVALUATION OF SILICA SAND AND KAOLIN REINFORCED SECONDARY ALUMINIUM MATRIX COMPOSITE: IMPLICATIONS FOR HEAT STORAGE APPLICATIONS

**OGUNRINOLA, IYANUOLUWA ENOCH**
**(13PCE00508)**

**OCTOBER, 2022**

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**BY**

**OGUNRINOLA, IYANUOLUWA ENOCH**
**(13PCE00508)**
**B.Sc Industrial Physics, Covenant University, Ota**
**M.Sc Industrial Physics, Covenant University, Ota**

**A THESIS SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF DOCTOR OF PHILOSOPHY (Ph.D) IN INDUSTRIAL PHYSICS IN THE DEPARTMENT OF PHYSICS, COLLEGE OF SCIENCE AND TECHNOLOGY, COVENANT UNIVERSITY, OTA, OGUN STATE, NIGERIA.**

**OCTOBER, 2022**

# ACCEPTANCE

This is to attest that this thesis is accepted in partial fulfilment of the requirements for the award of the degree of Doctor of Philosophy (Ph.D) in Industrial Physics, in the Department of Physics, College of Science and Technology, Covenant University, Ota, Nigeria.

**Miss. Adefunke F. Oyinloye**
**(Secretary, School of Postgraduate Studies)** **Signature and Date**

**Prof. Akan B. Williams**
**(Dean, School of Postgraduate Studies)** **Signature and Date**

# DECLARATION

**I, OGUNRINOLA, IYANUOLUWA ENOCH (13PCE00508),** declare that this research was carried out by me under the supervision of Prof. Marvel L. Akinyemi and Prof. Ahzegbobor P. Aizebeokhai of the Department of Physics, College of Science and Technology, Covenant University, Ota, Nigeria, and Dr. Henry O. Boyo of the Department of Physics, Elizade University, Ilara-Mokin, Nigeria. I attest that this thesis has not been presented either wholly or partially for the award of any degree anywhere else. All the sources of data and scholarly information used in this thesis are duly acknowledged.

**OGUNRINOLA, IYANUOLUWA ENOCH**

**Signature and Date**

# CERTIFICATION

We certify that this thesis titled **EXPERIMENTAL EVALUATION OF SILICA SAND AND KAOLIN REINFORCED SECONDARY ALUMINIUM MATRIX COMPOSITE: IMPLICATIONS FOR HEAT STORAGE APPLICATIONS** is an original research work carried out by **OGUNRINOLA, IYANUOLUWA ENOCH (13PCE00508)** in the Department of Physics, College of Science and Technology, Covenant University, Ota, Nigeria, under the supervision of Prof. Marvel L. Akinyemi, Prof. Ahzegbobor P. Aizebeokhai and Dr. Henry O. Boyo. We have examined and found the research work acceptable as part of the requirements for the award of Doctor of Philosophy (Ph.D) degree in Industrial Physics.

**Prof. Marvel L. Akinyemi**
**(Supervisor)** **Signature and Date**

**Prof. Ahzegbobor P. Aizebeokhai**
**(Co-Supervisor)** **Signature and Date**

**Dr. Henry O. Boyo**
**(Co-Supervisor)** **Signature and Date**

**Prof. Mojisola R. Usikalu**
**(Head of Department)** **Signature and Date**

**Prof. Clement O. Akoshile**
**(External Examiner)** **Signature and Date**

**Prof. Akan B. Williams**
**(Dean, School of Postgraduate Studies)** **Signature and Date**

# DEDICATION

I dedicate this thesis to Almighty God, the beginning and the end.

# ACKNOWLEDGEMENTS

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# ABSTRACT

Cost-reduction, increase in heat energy transfer and storage efficiency are key factors to be considered when harnessing heat energy, especially at the high-temperature range. Secondary aluminium, which has superior thermal properties, resistance to corrosion, and light weight compared to other thermal storage materials, was used as the matrix in this work. To influence the range of thermal applications of secondary aluminium, its specific heat and thermal conductivity were increased with reinforcements. There is scarcity of knowledge on the effect of varying the amount of silica sand and kaolin on the thermal properties of secondary aluminium. In this study, silica sand and kaolin were used to reinforce the aluminium matrix. The thermal insulation required for the fabrication chamber used to prepare the matrix and fabricate the composites was simulated to determine the optimal parameters. The secondary aluminium matrix was pre-processed using the constructed fabrication chamber. Ten (10) samples, including nine (9) composites and one (1) secondary aluminium as control, were prepared with the composition of secondary aluminium alloy ranging from 85 - 100wt% and composition of silica sand and kaolin ranging from 0 - 15wt%. Scanning Electron Microscopy (SEM) and X-Ray Diffraction (XRD) analyses were used to characterise the microstructure and phase composition of the composites. The specific heat, thermal conductivity, density, hardness and thermal diffusivity of the samples were determined. Artificial Neural Network (ANN) was used to simulate the thermal properties of more compositions using the properties of the already fabricated samples/composites. The data obtained were used to compare the properties of the composites obtained based on mixture theory. Optimal thermal insulation length of 20 cm on each side was obtained from the simulation for the fabrication chamber, considering an internal temperature of 800 $^{o}$C. The external length and breadth were 56 cm each, while the height was 60 cm. An average temperature difference of about 700 $^{o}$C was calculated between the inner and outer part of the simulated insulation layer; this temperature difference is very close to the simulated value of 730 $^{o}$C. Minima and maxima values of the thermal properties were observed in the composites. A maximum increase of 44% in the specific heat of the secondary aluminium was observed with the addition of 15% kaolin to the alloy. The maximum increase of 40.18% in the thermal conductivity of the alloy was observed with the addition of 10 and 2.5% silica sand and kaolin, respectively, to the secondary aluminium alloy. This study demonstrated that silica sand increased the thermal conductivity of the matrix because the relatively smooth surface of the particulates eliminated interfacial pores that serve as volumes of thermal resistance. Kaolin increased specific heat because the interfacial pores caused by the relatively rough surface of the kaolin particulates contained air with specific heat higher than those of the particulates and matrix. This study also revealed the potential of secondary aluminium reinforced with silica sand and kaolin as a viable heat storage material.

***Keywords: Silica sand, Kaolin, Hybrid composite, Secondary aluminium matrix, Thermal storage, Thermo-physical properties***