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Determining Thermal Characteristics of an Oil-Fired Crucible Furnace Using Clay and Alumina Bricks

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Abstract: *This paper explores the results of an experimental study that was intended to determine the thermal characteristics of an oil-fired crucible furnace using clay and alumina bricks. For the study, a refractory with 0.03118m³ combustion chamber capacity was used. The bricks analysis were carried out under transient condition that would be appropriate for laboratory and workshop with a capacity to reach 950°C within 20 minutes for aluminum and nonferrous scrap re-melting. The performance of the furnace was evaluated, and the results showed that the furnace can operate at a heating rate of 49.44°C/min, with a 29.70% efficiency determined, and which was within the efficiency range of conventional furnace. The heat transfer coefficient of 4.48W/m²K was obtained. Alumina bricks used in lining the furnace was attributable to its higher refractoriness. It was found that a better thermal shock was proved than clay bricks from the Comparative analysis simulation using commercial software ANSYS 14.0 aimed towards improving service life and efficiency.*

Keywords: *Aluminum, Secondary smelting, Refractory Bricks, crucible furnace, thermal efficiency, heat transfer coefficient*

1. Introduction

Aluminum is a renewable resource that has endless opportunities for generations to come (Osoba et al., 2018). Aluminum alloy manufactured components is well used in aerospace, automotive, packaging, offshore and marine constructions as it offers light weight, good corrosion resistance and excellent formability (Klauber et al., 2011; EAA, 2004). Aluminum and its alloy can be produced through primary and secondary smelting processes. Secondary aluminum often involve recycling aluminum scrap as the energy required for this process is ~5% of that required for primary aluminum production while yielding comparable quality aluminum as primary smelting (Das et al., 2007; Mukhopadhyay et al., 2005). One of the means by which secondary smelting of aluminum could be performed is through the use of crucible furnace that may be open or close. In the early nineteenth century, the phenomenon of crucible furnace was applied to the experimental melting of non-ferrous metals. However, the previously used crucible furnaces in local foundries are associated with the many problems namely: full exposure to heat and combustible products which are harmful to the body and health, loss of heat due to the open nature of the local furnace, which leads to prolonged operational activities with undesired result.

Based on the method of generating heat, furnaces are broadly classified into two types, namely combustion type (using fuels) and electric type. Based on the kind of combustion, it can be broadly classified as oil fired, coal fired or gas fired (Mehta et al., 2013). The majority of the heat loss i.e. around 40% of heat input is flue gas loss and only an estimated 10% of available heat is lost through the refractory wall during steady state operating conditions (Whipple, 2008; Owolabi et al 2016). Furnaces vary in design, geometry, production capacity (melting rate), materials of construction, and mode of operation (Daviess, 1970). One of the major challenge in design optimisation of the aluminum recycling process is numerical modelling of the furnace (Khoei et al., 1999; Khoei, 2000., Khoei et al 2002) in which this paper uses Ansys 14.0 to simulate the refractory bricks used for lining the furnace.

Ekpe et al. (2015) designed and fabricated an Aluminum Melting Furnace. Butane gas was used as the thermal energy source in heating up the system to the melting point of aluminum (660.4°C). Results showed great reduction in energy consumption and improved furnace efficiency of 28%. Many other researchers have worked on enhancing the performance evaluation of oil fired crucible furnace for melting al scrap, among others are Olukokun et al. (2019) with efficiency of 10.8%, Osarenmwinda (2015) with an improved furnace efficiency of 10.34%, Ighodalo et al. (2015) with a furnace efficiency of 11.5%, Adefemi et al. (2017) with an efficiency of 26.5%.

Furnace designs are made of different parts of different materials. The materials expand as temperature increases and contract as it decreases. This can lead to thermal fatigue causing cracking of the fuel fired crucible furnace linings. In practice, however, a lot of heat is lost