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HEAT CONDUCTIVITY FOR THE ALUMINIUM SCRAP IN A DE-COATING FURNACE

Ainul Nadirah Izaharuddin[1,2,3], Ahmed Rezk*[,1,2], Tim Hordley[3], Muhammad Imran[1,2], Stuart Allen[3]

[1] Energy and Bioproducts Research Institute (EBRI), College of Engineering and Physical Science, Aston University, Birmingham, B4 7ET, United Kingdom
[2] Mechanical, Biomedical and Design Engineering Department (MBDE), College of Engineering and Physical Science, Aston University, Birmingham, B4 7ET, United Kingdom
[3] Mechatherm International Ltd., Haden House, Cradley Heath, West Midlands, B64 6PU, United Kingdom

ABSTRACT

The aluminium scrap parameters in a de-coating furnace need to be examined in terms of the time and density of the scrap charged in that furnace. The current industrial challenge is to find the effective heat required to de-coat the aluminium scrap before the next scrap is charged. This may be quantified by determining the effective thermal conductivity (k-value) relative to scrap density, and this may be derived from calculating the general heat transfer coefficients during trials. The understanding of the heat transfer coefficient for the aluminium scrap inside a de-coating furnace is examined at a predefined operating temperature of 550°C. The k-value is identified through the experimental work that is presented here. This work develops a better understanding of the heat transfer behaviour during aluminium scrap piles de-coating, hence better simulation accuracy and energy efficiency studies.

1.0 INTRODUCTION

Recycling aluminium scrap back into new ingots is carried out by a broad range of manufactures and takes place at relatively lower cost, carbon footprint and energy compared to the same weight of aluminium through the primary smelter route and contributes significantly to the circular economy (Runton & Pilgrim, 2023). To produce secondary aluminium, de-coating of aluminium is essential to treat the aluminium scrap before melting it to increase the energy efficiency of the aluminium recycling process. The de-coating process removes several organic and inorganic compounds through thermal degradation or oxidation, where the chemical complex compounds are reduced to the basic forms, such as polypropylene, and this reduces the carbon monoxide (CO), carbon dioxide (CO_2), hydrogen (H_2), and water vapour (H_2O) (Evans & Guest, 2000). Nevertheless, understanding the heat transfer process during the de-coating process is crucial as it enables further study of the energy conversion efficiency through computational modelling. As such, Jaroni et al. (2012) presented the experimental work on the thermal profile of the bale at oven temperature 500°C to find the heat transfer coefficient of the bale scrap which showed 12.9 W/m^2K with 1.0 W/mK of thermal conductivity. Schmitz (2014) presented the heat transfer for the twin chamber and this showed the overall heat transfer at an industry scale. However, there is a gap in understanding the heat transfer process through the aluminium scrap during the de-coating process. It is important to find the lumped conduction heat transfer coefficient for the aluminium scrap while de-coating inside the furnace, to enable computationally simulating the heat transfer process. Furthermore, it is important to know the optimum time for de-coating in order to ensure the best time to charge for the next scrap into the furnace. Therefore, this study presents the initial experimental work of studying the heat conductivity of aluminium scrap blocks during the de-coating process under pre-defined heat transfer conditions.

*Corresponding Author

2.0 METHODOLOGY

The experimental set up consists of a 9 L Nabertherm Muffle Furnace of a programmable heating process and a block of aluminium scrap of dimension 155mm x 60mm x 70mm, as shown in Figure 1. The experimental setup mimicked the typical de-coating furnace at small scales. Three K-type thermocouples were used to measure the temperature inside the scrap at multiple locations to enable determining the lumped temperature variation overtime. The thermocouples were initially calibrated, and showed ±1.32-1.58% uncertainty range.

Figure 1 : (a) The aluminium scrap, (b) the aluminium scrap inside the oven

The furnace temperature was preheated for 30 minutes and maintained at 550°C. The temperature of the oven was recorded, and the temperature of the aluminium scrap was collected using national instrument DAC coupled with a LabView interface with one minute sampling rate. Therefore, the temperature inside the scrap was determined to find the thermal conductivity of the scrap inside the oven.

3.0 RESULTS

Figure 2 shows the dimensions of the aluminium scrap block used to determine the spatial temperature variation of the aluminium block.

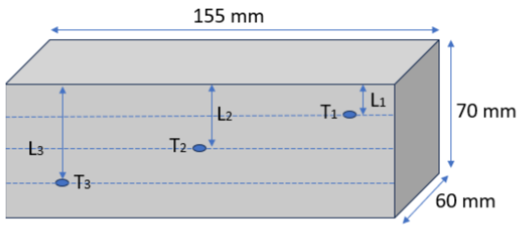

Figure 2 : The dimension of aluminium scrap

Figure 3 shows the scrap temperatures at different height as shown in Figure 2 for every thermocouple. Accordingly, the thermal conductivity of an aluminium scrap can be determined using equation 1. The average lumped thermal conductivity was found to be 4.0 W/mK, by using the Fourier's Law equation:

$$q = -k\nabla T = -k\left[\frac{\partial T}{\partial x}\,\hat{x} + \frac{\partial T}{\partial x}\,\hat{y} + \frac{\partial T}{\partial x}\,\hat{z}\right] \qquad (1)$$

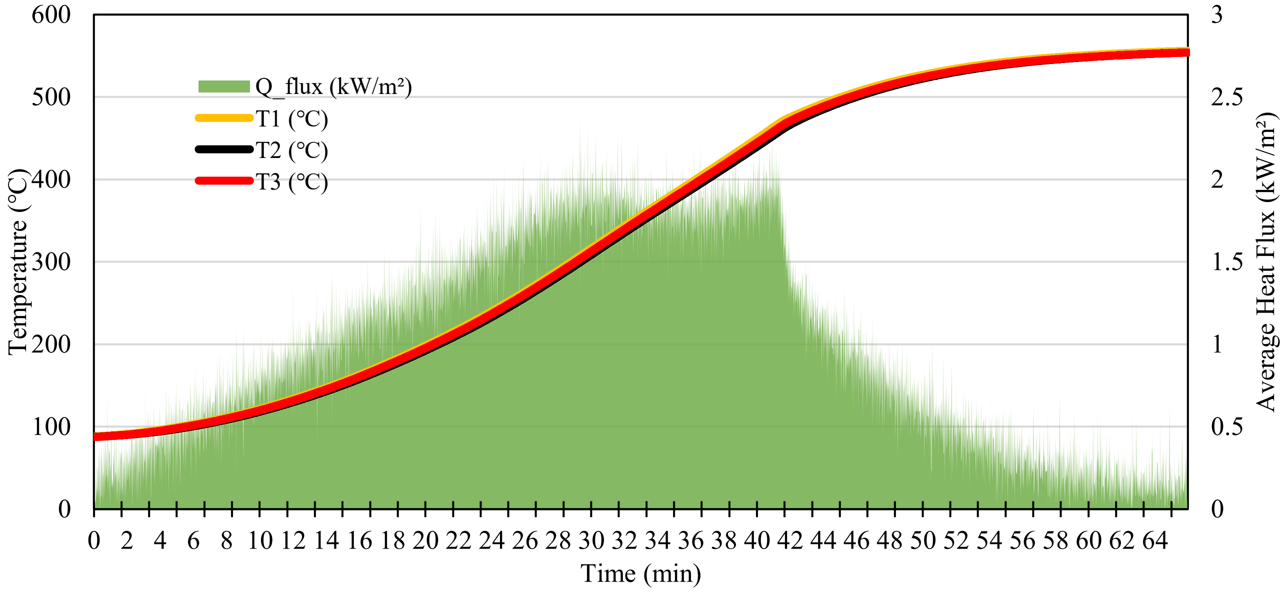

Figure 3 : The scrap temperature for 3 thermocouples with the average heat flux (kW/m^2) inside the oven at temperature 550°C

Figure 3 shows the temperature for 3 thermocouples with the average heat flux, to show the heat transfer per area that is impacting the scrap inside the oven. The heat flux increased until the oven temperature achieved 550°C; however, it started to decrease when the temperature became constant as there is no heat supplied to the scrap.

4.0 CONCLUSIONS

The primary goal of this paper was to experimentally determine the lumped thermal conductivity of the aluminium scrap blocks during the de-coating process. A small-scale furnace and aluminium block were utilised to mimic the actual de-coating process at 550°C, which is considered the optimum temperature for the aluminium de-coating process. The thermal conductivity calculations were presented, which will be a stepping-stone towards accurate simulation of the aluminium de-coating process. Additionally, this work is the initial step of determining the heat transfer coefficient, which does not consider the convection and radiation of the aluminium scrap surrounding inside the oven at 550°C. However, this will be specified in a future work.

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