Recycling Agricultural Waste from Palm Shells during Electric Arc Furnace Steelmaking

Abstract

The present study is focused on developing novel recycling of palm shell wastes as a carbon resource in electric arc furnace (EAF) steelmaking. Metallurgical coke was replaced by palm shells, and interactions with EAF slag were investigated at 1550 °C in a laboratory-scale reactor using the sessile-drop approach in an argon atmosphere (1 L/min). The palm shells were devolatilized in a nitrogen atmosphere at 450 °C, while coke was used without initial processing. The quantitative estimation of the slag droplet volume was performed using the V_t/V_0 ratio as a measure of slag foaming. For coke, the volume ratio decreased from 1.0 to 0.8 in the first 10 min with no considerable fluctuations. However, palm shell char showed considerably different trends with continuous fluctuations, reaching a maximum value of V_t/V_0 = 1.3, indicating a higher extent of gas entrapped into the slag matrix compared to coke. Off-gas emissions were monitored and correlated with dynamic changes in volume as a result of iron-oxide-rich EAF slag and carbon. The rates of total gas generation (CO + CO_2) from palm shell char were comparable to those seen in coke; however, the gases released from palm shell were an extent over a longer period of time, which allowed for their entrapment in the slag matrix, enhancing the volume of the slag. A thermogravimetric analyzer coupled with a mass spectrometer (TGA–MS) was used to study the behavior of coke and palm shells at high temperatures, with a focus on gas formation. The weight loss profiles, gas formation, and product distribution were significantly different between the two carbonaceous samples. It was found that more gases were released from palm shells than from the raw coke. Palm shells showed significant weight loss in the first 500 °C; however, a considerable amount of gases was evolved at temperatures higher than 1000 °C that might participate in the subsequent carbon/slag reactions. Optical microscopy images of the cross-section of the slag/palm shell sample showed trapped gas bubbles and reduced iron dispersed throughout the slag matrix. These results indicate that partial replacement of coke with palm shells is not only viable but efficient, leading to improved/sustained interactions with EAF slag.