# Abstract

The subject of this dissertation was the study of utilizing biomass materials as an alternative reducing agent in pyrometallurgical processes for the processing of oxide-bearing metal materials. The primary objective of the work was to determine the feasibility of using biomass for the reduction of metal oxides, aligning with current trends in heavy industry decarbonization and the Circular Economy. The utilitarian goal focused on determining optimal process parameters at a laboratory scale, which served as the basis for pilot-scale research, thereby enabling the future scaling of the technology to industrial conditions.

In the literature review section, an analysis of selected physicochemical properties of oxide-bearing metal materials was conducted, using metallurgical slags—the most significant group of such raw materials by volume—as an example. The thermodynamic principles of the reduction of metal oxides contained within them were also presented. Concurrently, studies on biomass were performed, covering its formation mechanism, classification, and selected physicochemical properties. The market potential of this raw material was discussed on a national, European, and global scale. Furthermore, a thermodynamic analysis of the possibility of using biomass as a reducer for metal oxides in slags was carried out.

The research part of the work was divided into two stages: Stage I – scientific tasks, and Stage II – implementation-oriented tasks. In Stage I, materials for testing were selected in the form of an oxide-bearing metal material and biomass. Copper metallurgical slag containing significant amounts of Cu and Pb was chosen as the oxide-bearing material. Twelve types of biomass were initially pre-selected as potential alternative reducers, based on literature data, availability, and previous research results regarding their use in reduction processes. Subsequently, the technological parameters of the slag, such as chemical composition, melting point, and viscosity, were determined. These formed the basis for establishing the smelting temperatures in the reduction tests. The composition and physicochemical properties of the selected biomass materials, specifically their calorific value and reactivity, were also determined. Following preliminary slag reduction tests, one target biomass material was selected—rapeseed cake—which was then used in laboratory reduction studies.

These tests were conducted in a temperature range of 1300–1450°C with the addition of the bioreducer at 2–20 wt.% relative to the slag mass. The process time was constant at 2 hours

for each experiment. For reference purposes, slag reduction was also performed using a traditional reducer in the form of coke. The main indicator for a positive evaluation of individual experiments was a post-reduction slag content of Cu and Pb </=1 wt.% for each element. Acceptable results were obtained at 1400°C with reducer additions >/= 15 wt.%, and at 1450°C for additions >/= 12 wt.%.

In Stage II, based on the laboratory tests, optimal parameters for pilot-scale reduction smelting were selected: a reducer addition of 12 wt.% relative to the slag mass and a temperature of 1450°C. Due to the high reactivity of biomass, a special method for its introduction into the process was developed; the charge was prepared in the form of briquettes containing slag, biomass, and binding agents. Pilot reduction tests in a demonstration submerged arc furnace (SAF) were carried out in three variants. In the first variant, the reducer was exclusively biomass; in the second, a mixture of biomass and coke; and in the third, coke alone. The post-reduction slag obtained from the first smelting did not meet expectations due to excessive Cu content. However, in the second trial, the post-reduction slag exhibited significantly better parameters: the Cu content was 1%, and Pb was 0.5%. Very similar results were achieved in the reference variant, confirming the high efficiency of rapeseed cake as a bioreducer.